

LINEAR MIXING MODEL APPLIED TO  
COARSE RESOLUTION SATELLITE DATA

Brent N. Holben  
Code 923  
NASA/GSFC,  
Greenbelt, MD. 20771

Yosio E. Shimabukuro  
Instituto Nacional de Pesquisas Espaciais - INPE  
São José dos Campos, SP, Brazil

## ABSTRACT

A linear mixing model typically applied to high resolution data such as Airborne Visible/Infrared Imaging Spectrometer, Thematic Mapper, and Multispectral Scanner System is applied to the NOAA Advanced Very High Resolution Radiometer coarse resolution satellite data. The reflective portion extracted from the middle IR channel 3 (3.55 - 3.93  $\mu\text{m}$ ) is used with channels 1 (0.58 - 0.68  $\mu\text{m}$ ) and 2 (0.725 - 1.1  $\mu\text{m}$ ) to run the Constrained Least Squares model to generate fraction images for an area in the west central region of Brazil. The derived fraction images are compared with an unsupervised classification and the fraction images derived from Landsat TM data acquired in the same day. In addition, the relationship between these fraction images and the well known NDVI images are presented. The results show the great potential of the unmixing techniques for applying to coarse resolution data for global studies.

## INTRODUCTION

The radiance recorded by the satellite depends basically upon the recording sensor's characteristics and the integrated sum of the radiances

of all surface materials and atmosphere within the instantaneous field of view (IFOV) of the sensor. Thus, the radiation detected will be influenced by a mixture of many different materials (mixed pixels) unless the target is composed of a single material (pure pixel). The spectral characteristics of the resolution elements of the National Oceanic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR) (1 km at nadir) are affected by this spatial problem. Several investigators have used the mixed pixel problem of small resolution multispectral satellite data to estimate the probability of its components. We present the following approach for the coarse resolution AVHRR data.

For global change studies, many investigators use the daily global coverage of the coarse resolution AVHRR data for land cover classification. Some workers based on mixture problem have developed a relationship between AVHRR information and high resolution data like TM (Iverson et al. 1990, Cross 1990). Quarmby et al. (1992) presented a linear mixture model for crop area estimation using multitemporal AVHRR channel 1 and 2 data. They assumed that each field within a ground pixel contributes to the signal received at the satellite sensor an amount characteristic of the cover type in that field and proportional to the area of the field. Also, for using multitemporal data, they assumed the proportions do not change between images. Cross et al. (1991) used a linear mixing model in Rondonia, Brazil and Ghana to monitor tropical deforestation. They used the first four channels of AVHRR. Two of the thermal infrared channels (3 and 4) were included because they were considered to contain important information for forest/non-forest discrimination (the forest canopy is relatively cool). This implied that each cover type is thermally distinct and the thermal response is linear. Because the monochromatic thermal

emission is governed by the Planck's equation, a linear model may introduce a significant error into the analysis.

A linear relation is used to represent the spectral mixture of targets within the pixel. The AVHRR has two channels located in the visible and near IR wavelength and one in the middle IR where the spectral responses are influenced by reflected and emitted radiance. In order to more accurately use the information contained in the 3.75  $\mu\text{m}$  channel, the reflective portion of this channel should be extracted. The reflective component should therefore lend itself to a linear model response to the mixed target.

There are several techniques to solve the mixture problem, such as Constrained Least Squares (CLS), Weighted Least Squares (WLS), and Quadratic Programming (QP) presented by Shimabukuro (1987) and the unmixing methods developed at University of Washington (Smith et al. 1985, Adams et al. 1986, Adams et al. 1989). These techniques have been applied for several high resolution data: Adams et al. (1986) applied to Viking images of Mars; Adams and Adams (1984), Shimabukuro (1987), Adams et al. (1990) applied them to MSS and/or TM data, and Gillespie et al. (1990) applied them to AVIRIS data.

The objective of this letter is to present a technique, using coarse resolution AVHRR data in the visible, near-IR and the reflective part of the 3.75  $\mu\text{m}$  band, to generate vegetation, soil, and shade fraction images. These images are formed by the proportion of each component within the AVHRR pixels. The Constrained Least Squares (CLS) method (Shimabukuro and Smith 1991) were applied to one AVHRR image covering an area in the central-western region of Brazil. The validation of the model for this kind

of data will be performed by comparing the resulting fraction images with the classification derived from TM/Landsat and AVHRR NDVI images.

### STUDY SITE

The study site is located between 17° 50' to 18° 20' South latitude and 52° 40' to 53° 20' West longitude on the border of Goiás, Mato Grosso and Mato Grosso do Sul States. The site includes the Emas National Park comprising about 131,000 hectares in which the "cerrado" vegetation is well represented (Redford 1985, IBDF/FBCN 1978, Pinto 1986). Located on the watershed between the La Plata and Amazon River basins, Emas Park is on the western edge of the Central Brazilian Plateau, adjacent to the Pantanal (Redford 1985). It offers a good sample of the Planalto habitats, including a number of small watercourses, the sources of two important rivers, riverine gallery forest and marshes, large areas of grassland (the "campos"), and some open woodland (the "cerrados") consisting of small thinly distributed trees seldom more than three meters high (Erize 1977). The surrounding land of the Park has been used for agricultural and cattle grazing. This Park is commonly affected by uncontrolled fires during the annual dry season (Shimabukuro et al. 1991). Most of these fires are set outside the Park by ranchers to improve grazing quality and to control cattle parasites (Redford 1985). The rest of the study site is covered by "cerrado" vegetation types. The Landsat/TM and NOAA/AVHRR data over this area acquired on July 29, 1988 were available for this study.

## METHOD

### AVHRR 3.75 $\mu\text{m}$ Reflective Component

The AVHRR 3.75  $\mu\text{m}$  band is a mixture of the thermal emitted energy and a reflective energy component. Typically the latter represents less than 10% of the signal for bare soil and urban features and less than 3 percent for green vegetation (Kerber and Schutt 1986; and Schutt and Holben 1991; Remer 1992). The reflective component may be approximated by assuming the emitted energy (brightness temperature) in the adjacent thermal band (10.5 to 11.5  $\mu\text{m}$ ) is related to the emitted energy in the 3.75  $\mu\text{m}$  band at ambient temperature through the Planck Function as follows (Kaufman and Nakajima 1992):

$$L_3 = L_{3\rho} + L_{3\varepsilon} \quad (1)$$

where:

$L_3$  = Total radiant energy measured by the satellite at 3.75 $\mu\text{m}$

$L_{3\rho}$  = The reflective energy at 3.75  $\mu\text{m}$

$L_{3\varepsilon}$  = The emissive energy at 3.75  $\mu\text{m}$

The reflective and emitted components may be expanded according to:

$$L_3 = \rho_3 F_0 \mu_0 / \pi + R_3(T_4) * (1 - \rho) \quad (2)$$

where:

$\rho_3$  = Reflectance in the 3.75  $\mu\text{m}$  band

$F_0$  = 3.75 band solar irradiance at the bottom of the atmosphere

$\mu_0$  = cosine of the solar zenith angle

$R_3(T_4)$  = Emitted radiance at 3.75  $\mu\text{m}$  using the 11.0  $\mu\text{m}$  brightness computed with the Planck Function

Solving for  $\rho_3$ :

$$\rho_3 = (L_3 - R_3(T_4)) / (F_0 \mu_0 / \pi - R_3(T_4)) \quad (3)$$

This formulation ignores the differential atmospheric transmission in both bands and we assume the target surface is flat and the satellite view direction is nadir.

The digital numbers from the satellite data are converted to brightness temperatures using the calibration coefficients and Planck Function coefficients given in the NOAA-9 users Handbook (Kidwell 1988). The parameters and variables used for the computation of the R3 and L3 radiances are given in table 1.

Table 1: The Planck Function parameters and constants for the R3 and L3 radiance computations.

Rad	Temp	$\lambda$	C1	C2	$F_0\mu_0/\pi$
L3	T3	3.75 $\mu\text{m}$	37413	14388	0.0008
R3	T4	3.75 $\mu\text{m}$	37413	14388	0.0008

#### Linear Mixture Model

A linear relation was used to represent the spectral mixture of materials within the resolution element. The response of each pixel in any spectral wavelength was taken as a linear combination of the responses of each component assumed to be in the mixed target. Thus each image pixel, which can assume any value within the image gray scale, contains information about the proportion and the spectral response of each component within the ground resolution unit. Hence, if the proportions of the components are known for any multispectral image, then the spectral responses of these components can be obtained. Similarly, if the spectral response of the components are known, then the proportion of each component in the mixture can be estimated. The basic mixture model may be formulated as:

$$r_i = a_{ij} * x_j + e_i$$

where:

$r_i$  = measured satellite response for a pixel in spectral band i

$a_{ij}$  = spectral response of mixture component,  $j$ , for spectral band  $i$   
 $x_j$  = proportion of mixture component,  $j$ , for a pixel  
 $e_i$  = the error term for spectral band  $i$ .

Subject to:

$$\sum x_j = 1 \quad \text{and} \quad x_j \geq 0 \quad \text{for all.}$$

### Approach

The Constrained Least Squares (CLS) method discussed by Shimabukuro and Smith (1991) was employed for TM and AVHRR data. This technique requires the spectral responses (radiance or reflectance) for the mixture components. We selected the spectral responses for vegetation, soil and shade to run the mixing model for TM data from the imagery by analyzing unsupervised classification results. They were selected choosing the most "pure pixel" inside the corresponding classes. To verify the selection, the error images generated by the model for each TM band were analyzed. This process was iterated until the acceptable error was achieved. Hence, the derived fraction images were considered as ground information for AVHRR imagery. Considering the coarse resolution of AVHRR, it is feasible to accept a "non pure pixel" for these data.

The spectral responses for vegetation, soil, and shade for AVHRR were estimated by using regression techniques (Richardson et al. 1975). A series of corresponding pixels were identified in both images (TM and AVHRR) and each AVHRR channel was regressed against TM fraction images. The spectral responses were derived from the regression coefficients and used as input for the model. The derived fraction images were compared to the ground information and TM results, related to NDVI images for model validation. The model performance can also be evaluated by analyzing the error images.

## RESULTS AND DISCUSSION

The reflective part of the AVHRR channel 3 was extracted using the technique described in the previous section providing the third channel to be used in the mixture model. The vegetation, soil, and shade fraction images were derived from Landsat/TM and NOAA/AVHRR data by applying the CLS method. The component proportions in these images are represented by the variation from dark gray level (small amount of the component) to bright gray level (large amount of the component).

The Landsat/TM data with high spatial resolution (30 meters on the ground) provided ground truth for the AVHRR data. An unsupervised classification of these data showed the complexity within the large scale land cover types. These data may be used to find a most pure pixel (assuming that a pure pixel for TM exists) instead of choosing the pure pixel directly from the image (generally used when this pixel are very distinguishable in the image). The classifier based on K-means identified 13 clusters that were related to possible different land cover types. These clusters were analyzed to identify areas with vegetation, bare soil and water and then compared to the ground truth reported by Shimabukuro et al. (1991). These clusters were rearranged into 7 classes: water and burned areas (blue); "cerrado" (light red); "campo cerrado" (red); "campo limpo" (dark red); bare soil 1 (light green); bare soil 2 (dark green); and cut areas (yellow), (figure 1).

The spectral responses for vegetation, soil and shade for running the mixing model for TM imagery were extracted from the image by analyzing the clusters. The spectral response for shade was searched in water and burned area clusters based on similar low spectral responses (Richardson

et al. 1975; Adams et al. 1986; Shimabukuro 1987; Gillespie et al. 1990). The spectral responses for vegetation and soil were searched inside the "cerrado" and cut area classes, respectively.

The coefficient of determination,  $r^2$ , and the mean spectral responses of vegetation, soil and shade for AVHRR channels were computed by regressing the component proportion derived from TM data against each one of the AVHRR channels (table 2). Vegetation, soil, and shade proportions in red, green and blue, respectively are showed in figure 2. As expected, there are no pure pixels for any one of the components assumed to be in the mixture. Comparing with figure 1 (classification result), the bare soil class has no red pixels, i.e., no vegetation proportion. Yellowish pixels have some amount of vegetation and soil (e.g. cut areas, grassland) and cyan represents pixels containing vegetation and shade amount within the pixel (cerrado class). Some noise is apparent in the picture due to cloudy pixels.

Table 2: Spectral responses for vegetation, soil, and shade for AVHRR channels estimated from TM fraction images utilizing regression model

Channel	$r^2$	DN		
		Vegetation	Soil	Shade
1	78.7	21.8	27.8	11.3
2	93.3	46.5	42.2	10.3
3Reflective	78.2	5.9	8.4	0.0

Figure 3 shows the NDVI, vegetation, soil and shade images derived from AVHRR data. There is a visual similarity of vegetation fraction and NDVI images. The NDVI values seem to be explained by those fraction images ( $r^2 = 95.2$  and  $90.0$  for TM and AVHRR, respectively). Since we have not done the cloud screening, it is noted the disagreement between

these images for the cloudy pixels. Table 3 shows the mean error for each TM and AVHRR channels. The results show the best fit for the near infrared channel for both sensors.

Table 3: Mean and Standard deviation of the error for TM and AVHRR data

Landsat/TM			NOAA/AVHRR		
Channel	Mean	Stdv	Channel	Mean	Stdv
TM3	3.46	2.68	1	0.29	0.93
TM4	0.22	0.44	2	0.00	0.04
TM5	1.51	1.37	3Reflective	1.13	2.15

Figures 4, 5 and 6 show the NDVI, vegetation and soil fraction images, respectively, derived from AVHRR data over a large area around the study site. The similarity between NDVI and vegetation fraction show the potential of the coarse resolution data for global studies. Again, it is noted the disagreement between these images for the cloudy pixels as mentioned above. In addition, the soil fraction image seems to be useful for deforestation studies since it contains information about soil proportion within the pixels.

### CONCLUSION

In the example cited, the reflective part of channel 3 shows ample sensitivity to various cover types to provide a suitable band for mixture modeling. Further assessment of the influence of the atmospheric transmission in the thermal bands is required to fully benefit from the surface characteristics of the band. This may require incorporation of ancillary data.

As the information contained in the current remote sensing resolution elements are quite often a mixture of several materials, the linear mixing models appear to be a useful tool for image analysis. The approach, analyzing the clusters derived from unsupervised classification and the iterative process analyzing the pixel that violates the constraints, showed to be a useful criteria to choose the "pure component" responses for the model. Also, the error images (for each TM and AVHRR channels) are useful criteria to evaluate the model performance.

The vegetation fraction image was in very good agreement with NDVI image, which shows the amount of green vegetation. Also, the soil fraction image containing information about non vegetation areas, seems to have a great potential for tropical deforestation studies using coarse resolution satellite data. In addition, the shade image contains information that can explain the vegetation index response, especially for the tropical forest which from the multi-layer structure has a high amount of shade.

Finally, the fraction images derived from AVHRR data can be used as additional channels for global studies.

#### ACKNOWLEDGEMENT

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## Figure Captions

Fig. 1. Land cover classification derived from Landsat TM data using unsupervised classification (K-means).

Fig. 2..Color composite of fraction image (vegetation = red, soil = green, and shade = blue).

Fig. 3..A) NDVI image, B) Vegetation fraction image, C) Soil fraction image, and D) Shade fraction image derived from AVHRR data over the study site.

Fig. 4. NDVI image derived from AVHRR data covering a large area around the study site.

Fig. 5..Vegetation fraction image derived from AVHRR data covering a large area around the study site.

Fig. 6. Soil fraction image derived from AVHRR data covering a large area around the study site.

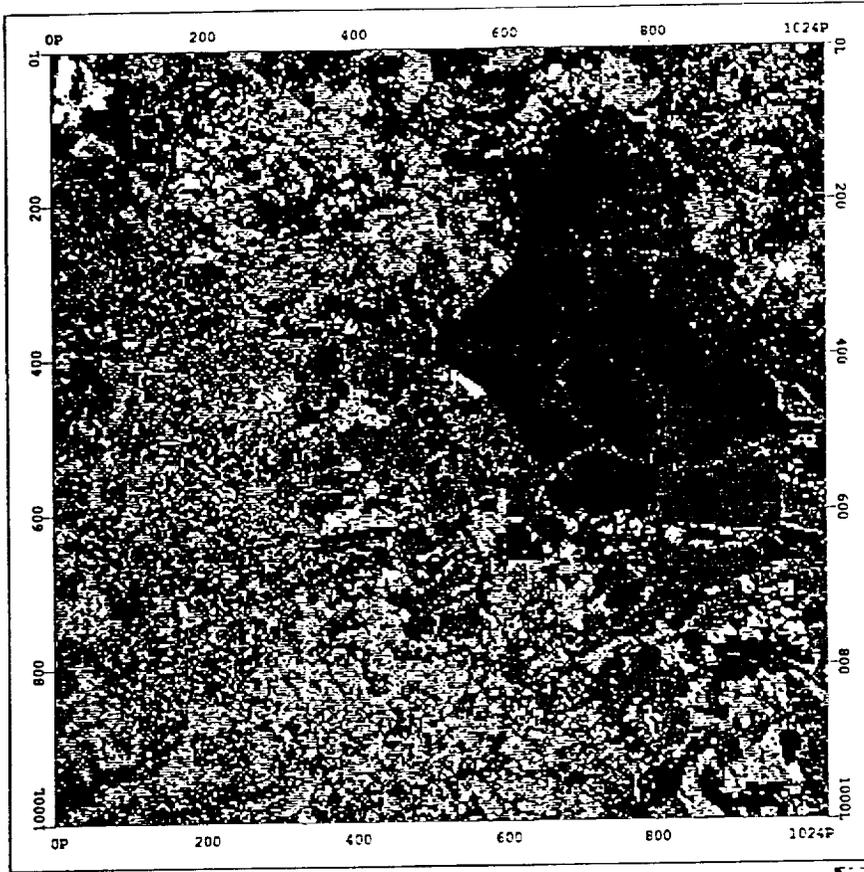


Figure 1

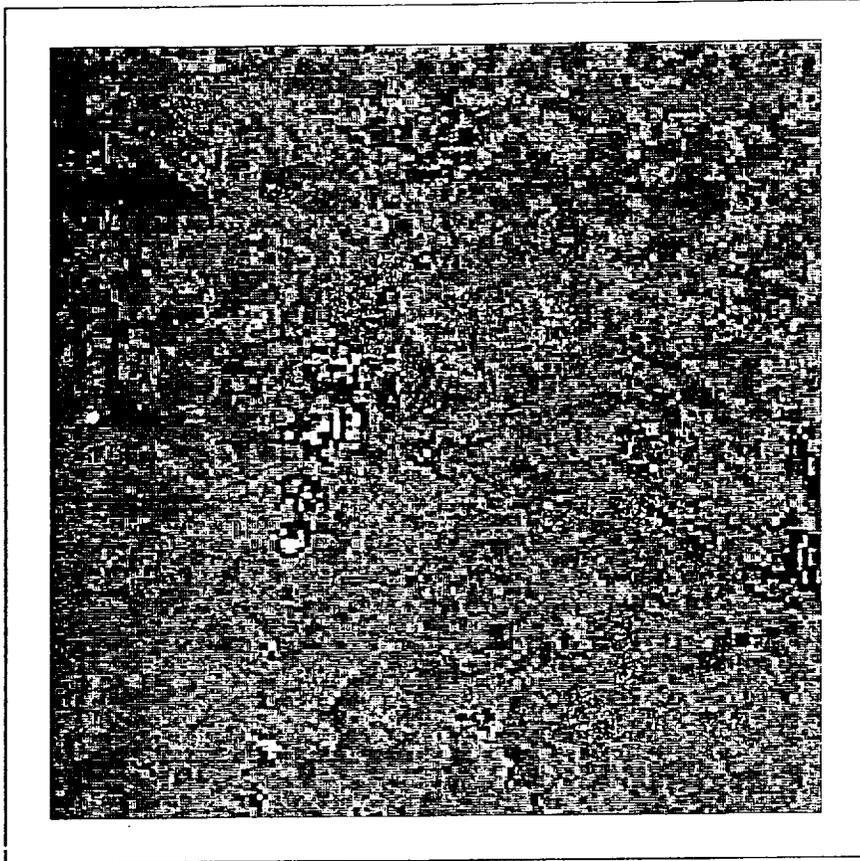
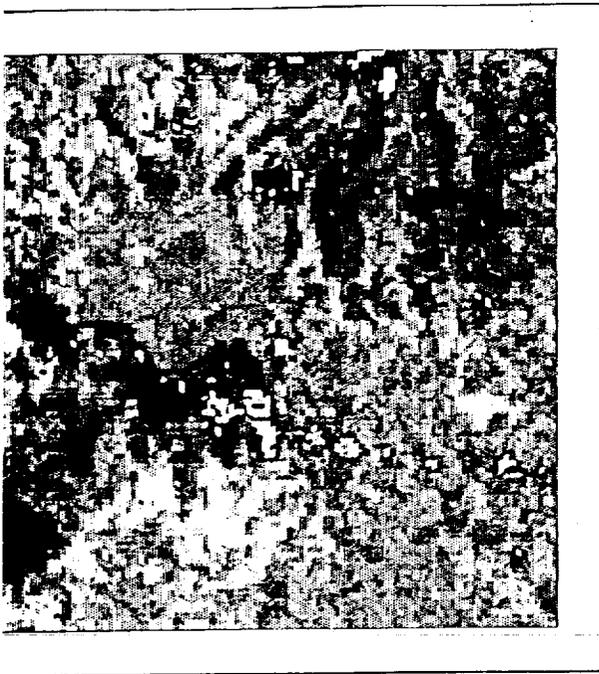
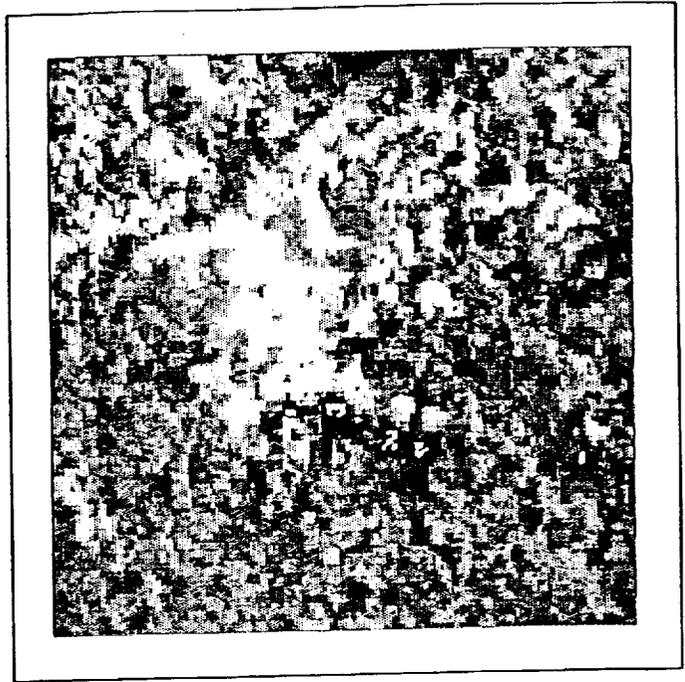


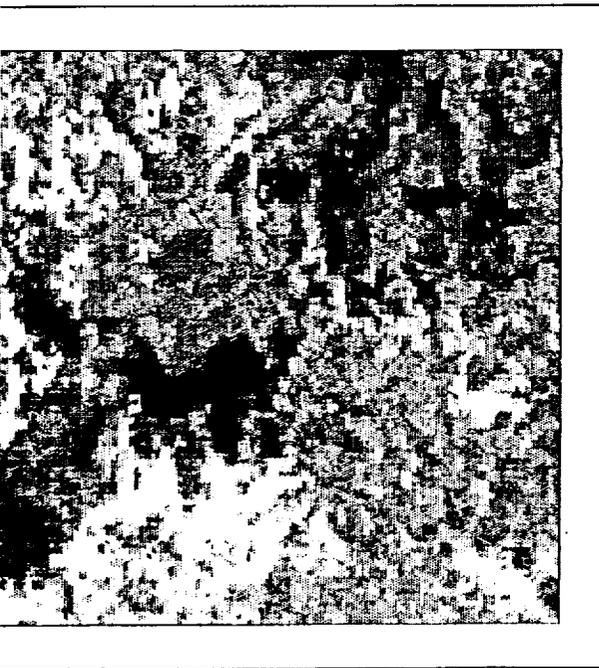
Figure 2



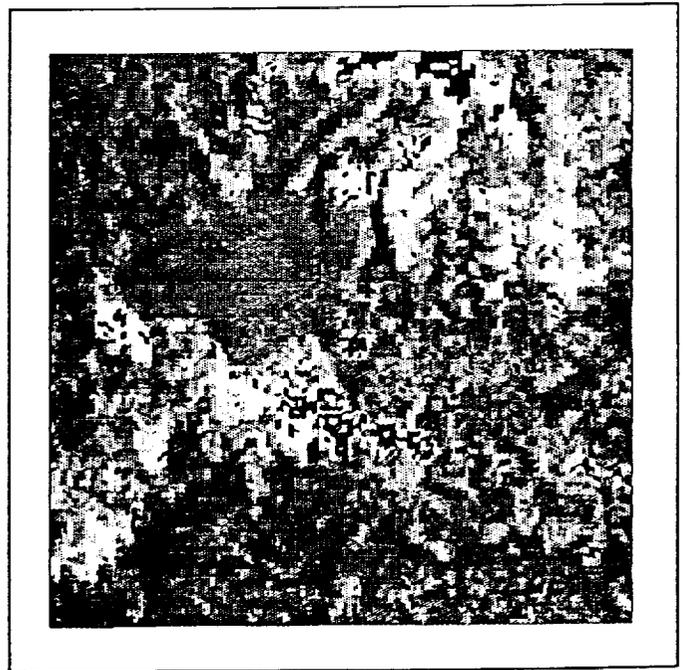
(B)



(D)



(A)



(C)

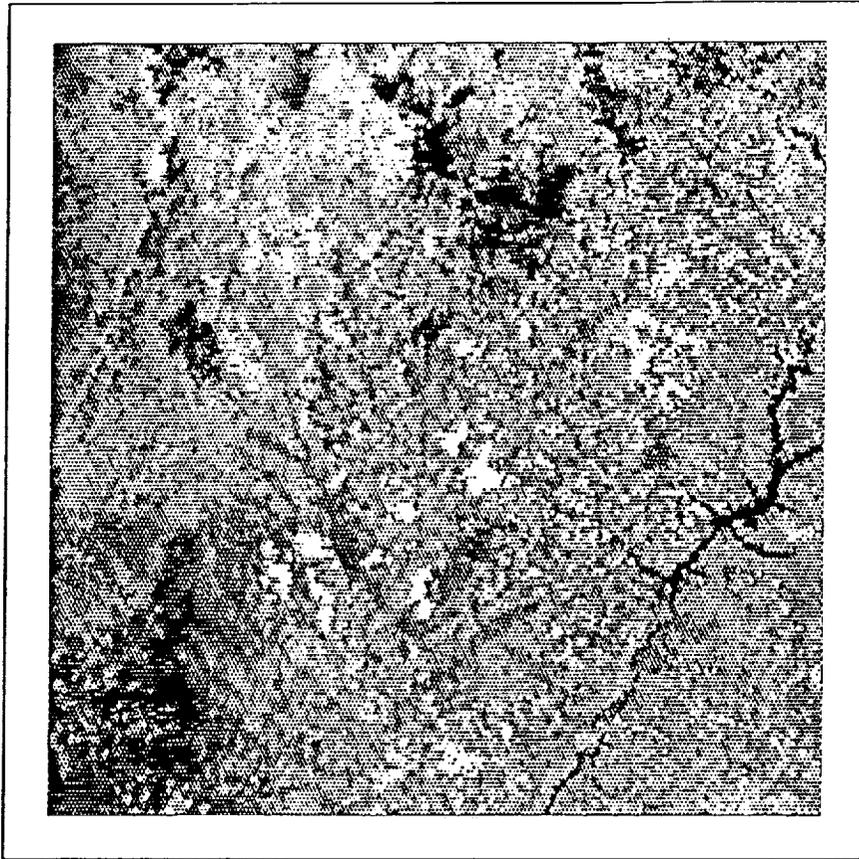


Figure 4

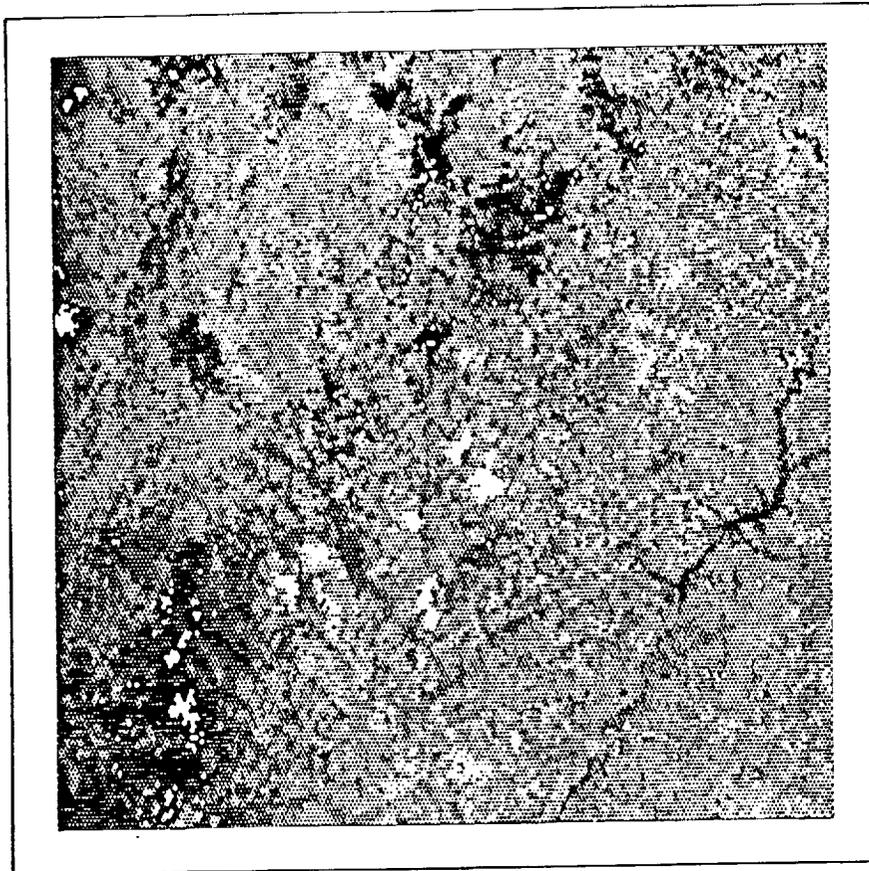


Figure 5

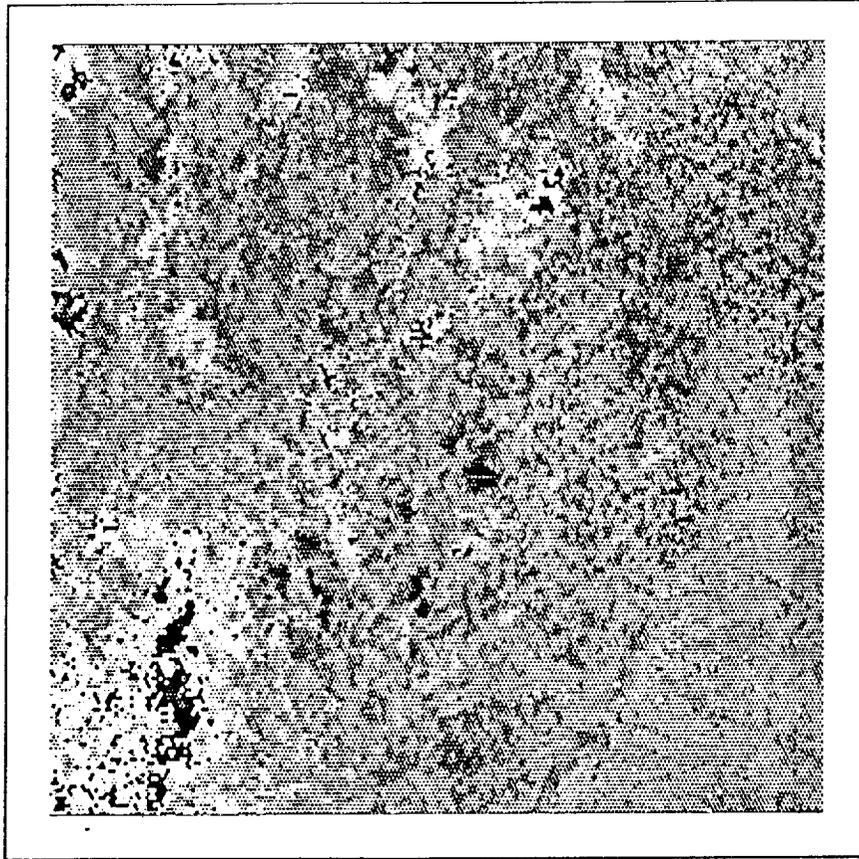


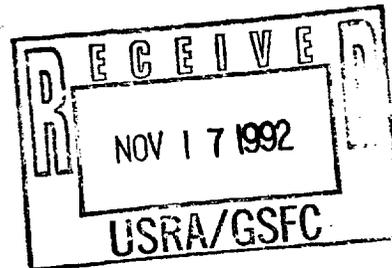
Figure 6



CENTER FOR REMOTE SENSING AND ENVIRONMENTAL OPTICS  
GIRVETZ HALL 1140  
SANTA BARBARA, CA 93106-3060

November 14, 1992

Dr. Frank Kerr  
USRA  
Code 610.3  
NASA Goddard Space Flight Center  
Greenbelt, MD 20771



Dear Frank:

Having been back in the University for six weeks now, I have had some time to reflect on my two years at Goddard as a Visiting Scientist employed by USRA. I found the job of the EOS Project Scientist enjoyable, productive, entertaining, and sometimes frustrating. But I encountered no frustration in dealing with the USRA staff, and I want to thank you for your hospitality, good will, scientific exchange, and excellent service.

For me, personally, and I suspect for almost every academic with a visiting appointment at a NASA lab, USRA offers the ideal vehicle. An appointment through a typical NASA support contractor would have been appropriate and inconvenient for several reasons, and I probably would not have accepted the Project Scientist task had it been available only through a for-profit company.

1. As the EOS Project Scientist, I had to participate in competition-sensitive deliberations. The prime example was the Source Evaluation Board for the EOSDIS Core System contract, but I also helped with the request-for-proposal for the EOSDIS IV&V con-

Internet: dozier@eos.ucsb.edu

OMNET: J.DOZIER

Voice: (805) 893-2309

Fax: (805) 893-2578

tract and participated in discussions about contracting plans for the EOS spacecraft and instruments. Because USRA—a non-profit, academically oriented association—does not compete for these types of contracts, I was able to avoid conflicts-of-interest that surely would have arisen had I worked for a for-profit company. One reason for a scientist to spend a year or two at GSFC is to more fully understand and contribute to the interplay between scientific and technical/engineering issues, and these exchanges and contributions can be more substantial if procurement issues are not excluded.

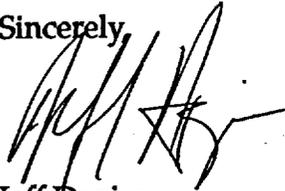
2. As a member of the academic community, I already had a retirement plan through TIAA/CREF, which is open only to non-profit institutions. The ability to continue to contribute to this retirement plan while away from my home university was a major benefit. Otherwise I would have lost two years of service.
3. USRA's other efforts to improve educational offerings in Earth and space sciences are significant, e.g. their consortium of universities working on an improved curriculum for Earth Systems Science. My association with USRA at Goddard has eased my participation in these projects.

I think USRA could help Goddard better address the use of temporary appointments for established academics. When I arrived in May 1990, Gerry Soffen said that he would consider Goddard successful if it could convince me to stay on after my initial two-year hitch. I thought then that he was setting up an unrealistic success criterion, and Goddard cannot be judged to have "failed" because I elected to return to UC Santa Barbara. My two years at Goddard were enormously productive, measured both by service to the scientific community and by personal professional growth, but, as you know, a Full Professor's position in a first-rate university is an awfully nice job, with professional and financial attractions that the government probably cannot match.

However, there is an important part of scientific research that universities are not equipped to handle well. In the Earth sciences, we in academia have few opportunities to work with the people who design and build instruments and spacecraft, bring data to Earth for analysis, and design, develop, operate, and evolve data and information systems. I think Goddard could profitably attract more visitors from the ranks of the senior, established academics, as well as continue to provide opportunities at the postdoctoral level. The scientists will learn more about design and implementation of the large projects that are essential to modern Earth science. The government will benefit from the experience of those of us who carry out small, self-contained projects with a minimum of overhead and paperwork.

Again, thank you for your help during my stay at Goddard.

Sincerely,



Jeff Dozier

Professor of Geography

cc: John Klineberg  
Vincent V. Salomonson  
Gerald Soffen  
Ghassem Asrar  
Dixon Butler  
Shelby Tilford

Mathew Schwaller   
NASA/GSFC Code 423  
13 October 1992

#### Quarterly Report to USRA

I joined the staff of USRA on 10 August 1992, assigned to the staff of NASA Code 423, the Earth Science Data and Information System Project (ESDISP). My ESDIP title is Manager of Science Data and External Interfaces. In this regard, I have accomplished the following.

Completed draft report on NASA Requirements for NOAA Data Sets. This report identifies NASA's near- and long-term requirements for NOAA data, and defines a process for implementing solutions to these requirements. I also examined some specific NASA scientific requirements for data from NOAA's National Meteorological Center and recommended a technical solution to these requirements.

Analyzed the compatibility of the Earth Observation System Data and Information System (EOSDIS) with the Department of Defense (DoD) Global Grid System (GGS). This analysis was used as ESDIP input to a briefing to the NASA Administrator.

Attended meeting of the Committee on Earth Observations Satellites (CEOS) Working Group (WGD) on Data in Frascati, Italy. This meeting concerned NASA's use of auxiliary data, i.e., data sets needed for processing satellite data. I gave a presentation on NASA's current use of auxiliary data, and NASA's plans to contribute auxiliary data sets for international users.

Activities ongoing into the next quarter:

I am currently in the process of contributing to the Earth Observations International Coordination Working Group's (EO-ICWG) Implementation Plan. This plan will outline the specific bilateral and multilateral implementations that need to be in place for the data systems associated with the International Earth Observing System.

I am also working on the the distribution policy for data sets provided by the European Center for Medium Range Weather Forecasting (ECMWF). At present, distribution of ECMWF data is relatively restrictive; we are looking for ways to simplify access to the data by NASA researchers.

I also have ongoing responsibility to update NASA's EOSDIS Science Data Plan. A revised version of the Plan is scheduled for the spring of 1993.

SEE: 8 1 700

SHRINIVAS MOORTHY

*Code 910.3,*  
*Data Assimilation Office*  
*NASA/GSFC, Greenbelt, MD 20771.*  
**(301) 286-6743**

**Activity report for the third quarter of 1992**

During this quarter I focused mainly on further development of a diabatic version of the Semi-Lagrangian Semi-Implicit (SLSI) GCM. Specifically, I have automated the model code with options to have either digital filter initialization, Diabatic Dynamic initialization or combination of both. I also improved the SLSI GCM code and found few bugs. I also found some problems near the poles and designed a filter to eliminate this problem.

Currently, I am planning for extensive evaluation of the GCM both with regard to short range prediction and in climate simulation. The main plan of work for the next quarter is to continue the development of Semi-Lagrangian GCM. Specifically we want to perform a few long simulations as well as some short range forecasts. I also want to get back to do some research on convective parameterization and improve RAS.

I did not perform any local or non-local travel during this period.

Report of Dr. Vikram M. Mehta's scientific activities during  
the last quarter (1 July 1992-30 September 1992)  
Contract number NAS5-30442, task number 910-007

### 1. Variability of global hydrologic cycle in the GFDL GCM

Earlier this year, we acquired a comprehensive data set from a 15-year integration of a high-resolution atmospheric general circulation model (GCM) from NOAA's Geophysical Fluid Dynamics Laboratory (GFDL). Analysis of rainfall in the GFDL GCM shows that the GFDL GCM can simulate seasonal and annual averages and intraseasonal variability of tropical rainfall well. It can also simulate the annual cycle (pattern and amount) of global rainfall quite well. Rainfall in the model's Asian monsoon region appears to undergo interannual variability even though there is no interannual variability in the external forcings of the model. Results of the rainfall analysis suggest that the GFDL GCM is a good tool to study global rainfall variability. Analysis of other components, e.g. evaporation, moisture transport, etc., is in progress. In preparation for Atmospheric Model Intercomparison Program, we are making a detailed comparison of the global hydrologic cycle and its variability in the GFDL GCM developed by Dr. Sud (code 913) at NASA/GSFC.

This work will continue during the current quarter. We expect to learn from this work how the global hydrologic cycle in the earth's atmosphere operates at a variety of time scales from a few days to a few years.

### 2. Coupled ocean-atmosphere variability

I am using my simple coupled ocean-atmosphere models and data from a variety of coupled ocean-atmosphere general circulation models to study variability of Atlantic region climate at time scales of years to decades. During the previous quarter I submitted, in collaboration with Drs. Paul Schopf (code 971), Max Suarez (code 913), and K.-M. Lau (code 913), a proposal to NOAA to study decadal variability of Atlantic region climate with complex models of the coupled ocean-atmosphere system. I have been informed by the program manager at NOAA that the reviews of the proposal are very good and that funding decision is likely to be made before the end of October.

My modelling work on interannual to interdecadal oscillations in the coupled ocean-atmosphere system continues to produce new results. I am preparing a paper titled 'Meridional oscillations in an idealized ocean-atmosphere system, Part II: Coupled ocean-atmosphere modes' for submission to *Journal of Climate*.

### 3. Non-local travel

- a. The Atlantic Climate Panel of the Committee for Climatic Changes in the Ocean invited me to give a seminar to the Panel at its meeting in Moscow (Russia) held from 13 to 17 July. The title of the seminar was **Interdecadal variability of Atlantic Ocean meridional circulations in a linear, coupled ocean-atmosphere model**. The National Science Foundation paid my travel expenses and local hospitality in Moscow was provided by the Russian Oceanography Institute.
- b. I presented two papers at the Second International Conference on Modelling of Global Climate Change and Variability held in Hamburg (Germany) from 7 to 11

September. The titles of the papers were **Interannual to interdecadal variability of meridional circulations in a linear, coupled ocean-atmosphere model** and **Rainfall variability in general circulation models: An inter-comparison study.**

QUARTERLY TECHNICAL REPORT  
(July 1 - September 30, 1992)

by Li Peng

WORK IN PROGRESS

The physical nature of the statistically obtained coupled tropical-extratropical modes was studied by examining the three dimensional structures of the modes which were constructed from the data of wind anomaly based on the time series projected onto the modes. A baroclinic extratropical structure generally suggests that the modes is likely developed outside the tropics, while a barotropical extratropical structure suggests that the mode is likely propagated from the tropics.

Barotropic fluxes of vorticity were computed for each of the significant modes using the wind data. It was found that the characteristics of the fluxes vary greatly with the modes.

It was also found by singular spectral analysis that the low-frequency oscillations have significant effects on intraseasonal oscillations. The coupling in the intraseasonal time scale often varies with the phase of the low-frequency oscillations.

The coding of the model of Lau and Peng (1986) was re-examined for the possibility of optimazation and incorporating a simplified boundary layer.

WORK PLANNED FOR THE NEXT QUARTER

To develop a nonlinear atmospheric model with a simplified boundary layer for use in a coupled ocean-atmosphere model.

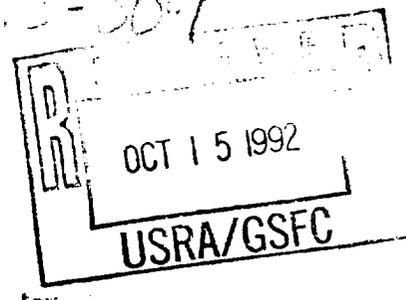
NON-LOCAL TRAVEL

Presented a paper entitled 'Coupled tropical-extratropical modes in East Asia and western Pacific.' at *The Second International Conference on East Asia and Western Pacific Meteorology and Climate*, in Hong Kong, from September 5 to 12, 1992.

USRA QUARTERLY REPORT FOR JULY 1 - SEPTEMBER 30, 1992

Joan E. Rosenfield

Activity: 5000-109



WORK THIS QUARTER:

1. I completed a paper entitled "Radiative Feedback of Polar Stratospheric Clouds on Antarctic Temperatures," and submitted it to Geophysical Research Letters. This paper argues that Antarctic winter and spring temperatures are warmer with the presence of PSCs than they would be without.
2. I finished my writeup on the intercomparison of heating rates and circulations for the Models and Measurements Committee, taking into account the comments made by participants on the draft I had submitted.
3. I did some calculations of the temperature implications of observed long term ozone trends (negative in the stratosphere and positive in the troposphere), using Hohenpeissenberg ozonesonde data supplied to me by Professor Julius London of the University of Colorado. Radiative equilibrium temperatures computed with a decadal trend were at most 1.25 K colder in the stratosphere and 0.1 K warmer in the troposphere, a very small signal.
4. I did some calculations of the radiatively determined temperature changes due to decadal CO<sub>2</sub> increases. The temperature change computed was not enough to explain the lower mesospheric temperature trend of roughly -1.5 K per decade, as analysed by Dr. Arthur Aiken of GSFC.
5. I began work on interpolating the Arctic Airborne Stratospheric Experiment II (AASE II) Northern Hemisphere heating rates onto potential temperature surfaces in order to determine the average heating and rate of descent inside the polar vortex during the time period of this aircraft mission. This is work which will be presented at the American Geophysical Society meeting in December.
6. I worked with Dr. Tina Wang of the Data Assimilation Office, serving as a consultant on the radiative transfer code in the assimilation model.
7. I served as a mentor for a student in the USRA Graduate Student Program.
8. I reviewed 3 papers for the Quadrennial Ozone Symposium, 1 paper for the Journal of Applied Meteorology, 1 proposal from NOAA, and 3 proposals from NASA.

PLANS FOR NEXT QUARTER:

1. Substantially revise the GRL paper in response to the referees' comments.
2. Continue work on AASE II heating rates.

3. Attend the AGU Meeting in San Francisco in December.
4. Compute thermal response to ozone depletions caused by solar proton events.
5. Begin examining the spectral, latitudinal, and altitude dependence of the solar irradiance as computed from the 2D model photolysis rate code, and the solar flux as computed from my heating rate code, in preparation for an intercomparison with observations which should be coming out of the Stratospheric Photochemistry, Aerosols and Dynamics Expedition (SPADE).

ROBERTA GAGLIARDI

## PHOTON COUNTING SYSTEM PROBLEMS

I studied the mode of operation of a photon counting system (PCs), widely used in the lidar system.

An electric signal corresponding to one photon arrives at a pulse height analyzer (P.H.A.). When a signal voltage exceeds a fixed base line voltage, the signal is counted as one pulse. This is the normal case occurring when the photons are individually distinguishable.

The problem encountered with such system is the following: when the signal levels increase, the response of PCs becomes non linear, that is, the output count rate is no longer proportional to the incident light intensity. Non linearity in a PCs' s response is caused by the overlapping of pulses and the finite response time of the electronics. In particular, depending on the pulse height distribution and the discriminator level, the overlapping of pulses (pulse pile-up) can cause count loss or even additional apparent count gain as the signal level increase. In fact, if two or more pulses, that would normally each individually be counted, arrive within too small an interval only one count will be registered. On the other hand, if two or more pulses that normally would not each individually be counted, arrive within too a small interval they may combine together to go over the discriminator level. Thus there are two related but competing processes occurring, one that tends to decrease the observed count rate and one that tends to increase the observed count rate. Therefore it is necessary to explore the extent to which high intensity PC signals can be quantitatively analyzed. Thus, the first data processing that must be done in the lidar system is the application of a correction to the PC data, which, taking into account the count loss and the apparent count gain caused by pulse pile-up, provides an analytical expression between the observed count rate and the true count rate. This correction depending on the kind of PCs.

In practise two fundamentally different types of Pcs can be recognized.

Let the input counting rate  $N$  be the counting rate which would be obtained if the dead time were zero, and the output counting rate  $n$  the rate when there is a dead time  $\rho$  after each output count. For non paralyzable system we assume that a new input count occurring during the dead time,  $t \leq \rho$ , after the previous output pulse, will not give an output pulse and also will not extended the dead time. A random input as always assumed. The problem is to find the relation between  $n$  and  $N$ .

The counting loss will be caused by those input counts which arrive during the dead time. Since each output count has a dead time  $\rho$  and there are  $n$  output counts per sec, on the average, the total dead time per sec is  $n\rho$ . The average number of input counts during the interval  $n\rho$  is just  $Nn\rho$ , so the loss is  $(N-n) = nN\rho$  per sec. The solution is:

$$N = n / (1 - n\rho) . \quad (1)$$

For paralyzable system we again assume that a new input count arriving during the dead time will not be counted, but it is assumed that the dead time is extended by the amount  $\rho$  after the (undetected) count arrives. Again the relation between  $N$  and  $n$  is desired. The system will remain blocked if the input counts are always spaced by

less than rho. In general, another output pulse is obtained every time a timing spacing  $\geq$  rho occurs between successive input counts. Thus,  $n = N$  (probability of zero counts during the time rho after a given count). In order to calculate this probability, we have to introduce the Poisson distribution. In fact, for random sequence, the probability of observing x events in any given time interval t is given by the Poisson distribution:

$$P_x(t) = \frac{m^x e^{-m}}{x!} \quad (2)$$

where m is the average number of events occurring in each interval t. For an event to be recorded by a paralyzable counter, we require that no counts be received in a given interval rho, the probability of this occurring is given by:

$$P_0(\rho) = \frac{m^0 e^{-m}}{0!} = e^{-N\rho} \quad (3)$$

where  $N\rho$  is the mean number of input counts expected during the time rho.

Thus

$$n = N e^{-N\rho} \quad (4)$$

This is the general approach to the problem. I studied, in particular, a new method to correct the lidar data for paralyzable system, proposed by Donovan et al. in the Sixteenth International Laser Radar Conference on July 1992. They proposed a new model that describes the non-linear count loss and apparent count gain arising from the overlap of the photomultiplier tube (PMT) pulses, taking into account the distribution in amplitude of the PMT output pulses and the effect of the pulse height discrimination threshold.

The starting point is the eq 4; the problem is that the analyst records the output count rate n and needs to derive the input count rate N with some specified level of accuracy. Usually one can use the series expansion of the exponential in eq 4, followed by dropping of quadratic and higher terms and insertion of the approximation  $N\rho \approx n\rho$ . The idea of Donovan et al. is the following: starting by eq 4, we can write:

$$n = N P_a \exp(-N\rho) + N P_{1b \wedge 2a} (N\rho) \exp(-N\rho) + N_{2b \wedge 3a} \frac{(N\rho)^2}{2} \exp(-N\rho) + \dots \quad (5)$$

where  $P_a$  is the probability that a individual pulse is above the discriminator threshold,  $P_{1b \wedge 2a}$  is the probability that given two overlapped pulses, that the first pulse's amplitude is below the discriminator threshold while the sum of the second pulse's amplitude plus the amplitude of the first is above the threshold. In general,  $P_{ib \wedge (i+1)a}$  is the probability that given i+1 overlapped pulses that the sum voltage of the first i pulses is below the discriminator level while the addition of the i+1 pulse causes the voltage to go above the discriminator threshold. it easy to see that for the case of uniform pulses which are above the discriminator level will have  $P_a=1$  and  $P_{1b \wedge 2a} = P_{2b \wedge 3a} = \dots = 0$  and thus eq 5 reduces to eq 4. We also can see that the first term in eq 5 take into account the count loss while the remainder terms take into account the apparent count gain. I studied the application of this model to the data and the results obtained by Donovan et al. I also studied the possibility to extend this approach to the real lidar data taken by a Raman lidar placed at the GSFC.

QUARTERLY TECHNICAL REPORT

Kenneth E. Pickering  
Code 916, NASA/GSFC

Progress -- July 1, 1992 - September 30, 1992

Work has been progressing in four main areas:

(1) Modeling the effects on free tropospheric ozone production of deep convective events

This is a joint effort with Code 912 in which selected squall lines are simulated with the 2-D Goddard Cumulus Ensemble Model and the resulting wind fields are used to transport trace gases that are critical for photochemical ozone production. I then use particular profiles from the resulting trace gas distributions in a 1-D photochemical model to estimate the effects of the convection on ozone production during the 24 hours following the convective event.

During this period I was notified that our revised JGR manuscript regarding the effects on ozone production of the entrainment of urban plumes into deep convection was accepted for publication and is now in press.

I met with John Scala (Code 912) and with Russ Dickerson and Olga Poulida from the Univ. of Maryland concerning the June 28, 1989, event from the North Dakota Thunderstorm Project. I have reviewed the meteorological and trace gas data from this event in preparation for model analyses. I have also reviewed initial cloud model results produced by John Scala for this event.

2) Modeling the effects on upper tropospheric ozone of deep convective events during STEP

This is again a joint effort with Code 912, as above. Trace gas data from the NASA ER-2 is being used to compute ozone production rates in the upper troposphere for the 24 hours following the deep convective events that were observed in the Stratosphere-Troposphere Exchange Project (STEP).

During this period I completed the text and figures of a paper entitled, "Upper Tropospheric Ozone Production Following Mesoscale Convection during STEP/EMEX". I submitted the manuscript to JGR.

(3) TRACE-A experiment

Anne Thompson and I have been selected by the NASA HQ Tropospheric Chemistry Program to participate in the next Global Tropospheric Experiment (GTE) field project, Transport and Atmospheric Chemistry near the Equator - Atlantic (TRACE-A), to be conducted in the August-October, 1992 time frame.

During this reporting period all plans for the project were finalized and the Brazilian portion of the experiment was executed. The planning activities included many communications with the GTE meteorological support team at NASA LaRC and the Mission

Meteorologists at Florida State University concerning the available data and facilities in Brasilia for the field project. My activities have also included contacts with the Brazilians regarding soundings to be taken during the experiment. Many discussions were conducted between Anne Thompson, Donna McNamara, Arlin Krueger and myself concerning final plans for sending TOMS total ozone data to the field during the experiment.

I was stationed in Brasilia for two weeks during the initial phase of the field experiment. During this time I assisted in the installation of a temporary satellite data receiving station for geostationary satellite cloud imagery. I actively participated in analysis of synoptic weather conditions, assessment of the possibility of convective activity over the flight region, and in the planning of four specific flights of the NASA DC-8. I rode on the DC-8 for two of these flights, recording significant meteorological and chemical phenomena and photographing biomass fires and convective clouds.

#### (4) Pre-TRACE-A Ozone/Fires Trajectory Analysis

Work has progressed on a project to link TOMS total ozone maxima over the South Atlantic with biomass fire counts for Africa for 1989. I have conceptualized this project and am now supervising and providing guidance to an M.S.-level atmospheric scientist doing the bulk of this work.

We have been using global meteorological data sets with an isentropic trajectory model. Work has proceeded primarily along two lines: (1) examining linkages between specific TOMS maxima and the fire data for specific days and (2) conducting a trajectory intercomparison, using different input data sets.

The proceedings paper for the 1992 Quadrennial Ozone Symposium which describes our results for the first activity was accepted for publication. Minor revisions were made to text and figures and the camera-ready copy was submitted for publication.

I continued the trajectory intercomparison work by computing trajectories over the South Atlantic using two additional input data sets.

#### (5) Miscellaneous activities

a) Participated in initial planning meeting for a future NASA Global Tropospheric Experiment convective transport study. Also contributed to the project "white paper" that was submitted to NASA headquarters.

b) Contributed to Yoram Kaufman's proposal to NASA headquarters concerning urban aerosol fluxes.

#### Planned Activities -- October 1, 1992 - December 30, 1992

(1) Perform further analysis of trace gas measurements from June 26 PRESTORM event. Begin photochemical simulations for this event following receipt of tracer files from Code 912. Coordinate analysis of June 28, 1989, North Dakota event with John Scala (Code

912) and Russ Dickerson and Olga Poulida from Dept. of Meteorology, University of Maryland.

(2) Continue participation in TRACE-A field program by processing real-time TOMS total ozone data and sending it to the field project offices in Johannesburg, Windhoek, and Ascension Island. Begin formulation of plans for analysis of field data and for model simulations.

(4) Continue coordination of ozone/fire trajectory analysis. Perform more case studies using TOMS total ozone and fire count maxima. Complete trajectory intercomparison study. Prepare journal paper.

## USRA Technical Report for Third Quarter 1992

Leslie R. Lait (Task 910-032)

October 23, 1992

During the third quarter of 1992, work continued on the constituent reconstruction technique. This technique, which involves constructing composite constituent fields in (potential vorticity, potential temperature) space, has been applied to data collected during the 1991-1992 AASE-II field experiment as well as ozonesonde data from EASOE, a European campaign from about the same time. In addition, work was begun to apply it to data from the UARS satellite. The UARS research is being done with Gianlucca Redaelli, a graduate student visiting from the University of L'Aquila, Italy.

In preparation for re-analysis of previous field missions' data using the same technique, data from those missions has been installed and integrated into the data analysis system on our computer workstations.

Preparations are also underway for the upcoming Stratospheric Photochemistry, Aerosols, and Dynamics Experiment (SPADE), which will be staged from NASA Ames Research Center in November. New versions of our group's mission plotting and analysis programs are being written, including a complete reworking of our display of meteorological data from radiosondes.

Work continued on a document describing the data format standard created by Eric Nash and myself. This format for electronic exchange of scientific data has generated considerable interest in our branch, and current plans call for this document to be published as a NASA technical report.

Two research proposals from NASA Headquarters were reviewed during this period.

Finally, I gave a talk on the ozone layer to a church group on September 12.

Work planned for the fourth quarter of 1992 includes:

- Participation in the SPADE mission in California.
- Continued analysis of mission constituent data in potential vorticity/potential temperature coordinates, with particular emphasis on UARS data.
- Re-analysis of previous missions' constituent data for comparison with AASE II data

*Leslie Robert Lait*

*10/23/92*

Leslie Robert Lait

# Quarterly Technical Report

To: Universities Space Research Association  
From: Si-Chee Tsay  
Date: 14 October 1992

## A. Travel:

During this quarter I had an invited trip to Colorado State University from September 24-30 to work with Prof. G. Stephens' group on multi-dimensional radiative transfer problems. They have paid all the expenses.

## B. Work in progress or results obtained (1 July - 30 September 1992):

In the past quarter, I have worked on the following research topics:

1. analyzed some interesting radiation measurements (LEADEX) over the arctic environment. In LEADEX, we have gathered the surface bidirectional reflectivity for snow, one-year and multiple-year sea ice, under clear and cloudy sky conditions.
2. completed the setup of running the netCDF formatted data (MODIS selected format) on the Cray-YMP for the first time. An interesting case (cloud microphysics and radiation interaction) on June 17 during ASTEX has been selected for retrieving the effective radius and optical thickness of these clouds. These results have been presented in Japan by Dr. M.D. King and in Colorado State University during my visit (9/24-30) to Prof. G. Stephens' group.
3. conducted the forward simulations of the multiple scattered radiation field at 0.63 and 0.82 microns for water and ice clouds at different values of the effective radius. This project is connected to Dr. Y. Kaufman's study on atmospheric correction.
4. re-composed the microphysics data of Kuwait oil fires to compute their optical properties. The results of simulated radiance field will be compared with the measurements from CAR.
5. completed the computation of spatial distribution of radiative heating rate for two-dimensional media. This project is collaborated with Drs. Stephens and Gabriel in Colorado State University.

## C. Work planned for next quarter (1 September - 31 December 1992):

For the coming quarter, I plan to work mainly on the following research:

1. attending the MODIS Science Team meeting in Santa Barbara (October 27-

- 29) with Dr. M.D. King and attending the FIRE Science Team meeting in Fairfax (November 9-13) to present some results from ASTEX experiment.
2. continue to write up the update paper of DisORT version 2 for submission to Journal of Applied Optics.
  3. continue to analyze the bidirectional reflectivity measurements obtained in LEADDEX and ASTEX experiments. This research will contribute two papers which are tentatively entitled "Observational and theoretical studies to bidirectional reflectivity. Part I. Various types of surface; Part II. Water and ice clouds" by Tsay, S.C. and M.D. King.
  4. continue to analyze the CAR data, generated by Dr. King's instrument in Kuwait oil fires. This case study of scattering pattern by oil drizzle will contribute to a research paper which is tentatively entitled "Simulation of directional and spectral reflectance of the Kuwait oil fire smoke" by Tsay, S.C. and M.D. King.
  5. re-examine more carefully the retrieval of cloud optical and microphysical properties by using data gathered from MAS (MODIS Airborne Simulator) mounted on NASA ER-2 aircraft.

910-12L

TECHNICAL REPORT

10/27/92

STEPHEN C. BLOOM

(TASK NUMBER 5000-136)

Work continued on the error simulation project during the last quarter. An extensive series of diagnostic tests have been required to track down various errors in implementing the algorithm. In addition, R. Atlas and I have decided to send a Note to the Monthly Weather Review summarizing the earlier results of this project; namely the difference in correlation structures of O-F between real data assimilations and simulated data assimilations. We feel that this is an important result to communicate to the meteorological community, especially in light of a growing interest in performing OSSE's for upcoming new observing systems (LAWS, EOS, etc.).

Priorities for the upcoming quarter are: (1) OSSE Note; (2) General Balance Method, finish evaluation of this methodology of assigning directions to SSM/I surface wind speeds; (3) work with DAO personnel on publishing IAU results; and (4) assimilation experiment with correlated simulated errors, assess the impact of the approach and determine if further work is warranted. A new area of work is beginning which will involve my continued interaction with DAO. This will be a project to recast and generalize the current OI analysis algorithm into a 3-dimensional variational analysis; an analysis system of this form will have a much greater potential for utility to the research efforts of the Satellite Data Utilization Office. Currently, planning meetings are being held to map out the best strategy to undertake this large task. I anticipate that the 3-d variational system will be a superior framework for the assimilation of LAWS and new types of surface data.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

QUARTERLY TECHNICAL REPORT  
(July-September 1992)

Employee Name: Dr. R. Wayne Higgins

Task Number: 910-037

1. Work Completed:

Currently, we (with Ray Bates and Shrinivas Moorthi) are working with the model development group of the DAO (under Larry Takacs) to merge the hydrodynamics from our semi-Lagrangian finite difference global multilevel model with the GEOS-1 model in order to carry out a diagnostic intercomparison of semi-Lagrangian and Eulerian approaches. The code that we provide should be "modular" so that it is easily incorporated (i.e. portable) into the GEOS-1 system. The paper on which this model is based (Bates *et al.*, 1993) and the note which describes the fast solver (Moorthi and Higgins, 1993) used in the code will both appear in the January issue of the Monthly Weather Review. The results of a 1 year integration of this model were discussed at the Second International Conference on Modeling of Global Climate Change and Variability in September in Hamburg, Germany. Our NASA Technical Memorandum based on a more comprehensive summary of the solver (including a copy of the computer code) appeared during this quarter. We continue to work on the second part of our study concerning the semi-Lagrangian model with full physics. This involves further evaluation of the performance of the model, especially near the pole, where some noise in the divergence field still occurs. We plan to carry out an ensemble of 10 day forecasts in order to analyze the predictive capability of our model, and then to write up the results (Moorthi et al, 1993).

Seigfried Schubert and I have begun a series of studies to diagnose the "climate characteristics" of data sets produced in the DAO with particular emphasis on the (physical and dynamical) structure of the synoptic-scale eddies and their connection to the large-scale flow. In this quarter we focused on relationships between the eddies and blocking events. The areas we are investigating include the characteristics of northern hemisphere blocking in GCMs and observations, the "climatological lifecycle" of blocking events (and associated eddy activity) using a zonal index, and the role of the synoptic eddies in directly forcing blocking events. Work in this area will continue. Recently, I was invited to speak on this work (and the work of Higgins and Schubert, 1993) at the Laboratory for Atmospheres Winter-Spring Seminar Series.

In July at the Data Assimilation Offices' annual RTOP Review I discussed recent work (with Siegfried Schubert), on the relationship between boreal winter synoptic-scale transient eddies and low-frequency zonal wind variability (Higgins and Schubert, 1993). Our work will also be discussed at the Seventeenth Annual Climate Diagnostics Workshop in October, 1992 in Norman, Oklahoma.

## II. Papers Published or Accepted for Publication:

Higgins, R.W. and S.D. Schubert, 1993 Low-frequency synoptic-eddy activity in the Pacific storm track, ( to appear in J. Atmos. Sci. in April).

Moorthi S. and R.W. Higgins, 1993: On the direct solution of 2-D separable elliptic equations on the sphere, (to appear in Mon. Wea. Rev. in January).

Bates, J.R., S. Moorthi and R.W. Higgins, 1993: A global multilevel atmospheric model using a vector semi-Lagrangian finite difference scheme. Part I: adiabatic formulation, (to appear in Mon. Wea. Rev. in January).

## III. Technical Memoranda

Moorthi S. and R.W. Higgins, 1992: A fast direct solver for 2D separable elliptic equations on the sphere, NASA Tech. Mem., 104567.

#### IV. Papers Submitted for Publication

Li, Y., I. M. Navon, S. Moorthi, and R.W. Higgins, 1993: The 2-D semi-implicit semi-Lagrangian global model: direct solver and adjoint model development, (submitted to Mon. Wea. Rev.)

#### V. Papers Presented at Scientific Meetings:

Bates J.R., S. Moorthi and R.W. Higgins, 1992: Development of a semi-Lagrangian global atmospheric model. Second International Conference on Modeling of Global Climate Change and Variability, Hamburg, Germany, Sept. 7-11.

Higgins, R.W. and S.D. Schubert, 1992: The interaction between low-frequency synoptic-eddy activity and baroclinic wave packets. Seventeenth Annual Climate Diagnostics Workshop, Norman, Oklahoma, October 19-23.

October 13, 1992

TO: Denise Dunn, 610.3, USRA

FROM: Michael Fox-Rabinovitz (Task Number 910-038)

SUBJECT: Quarterly Technical Report (July 1, 1992 to September 30, 1992)

My activities included the following:

1. Design of the new vector spherical harmonics filter, and continuation of testing the scalar spherical harmonics filter for the 17-layer GLA GCM; completion of the paper on computational dispersion properties of vertical grids for atmospheric and ocean models; participation in testing the frozen version of the GEOS GCM.
2. Continuation of testing diabatic dynamic initialization with the 46-layer stratospheric model.
3. Presentation of the proposal on diabatic dynamic initialization for FY93-95 at the NASA RTOP review meeting.
4. Reviewing NASA and NSF proposals.
5. Participation in organizing committee activities for the Yale Mintz Memorial Symposium.

Work planned for the next quarter will include:

Submitting the paper on computational dispersion properties of vertical grids for atmospheric and ocean models; continuation of testing the scalar and vector spherical harmonics filters for the GLA GCM; continuation of testing diabatic dynamic initialization for the stratospheric domain; participation in activities of the NAS/NRC Board on Atmospheric Sciences and Climate (BASC); presentations on behalf of the BASC to the NRC Board on Mathematical Sciences, and to the Climate Research Committee.

  
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## Quarterly Report of Dr. Suhasini Ravipati

from (July 1 -- Oct. 30 ) 1992

Task Number / NASA5-30442

Task Originator/ Dr. Thomas . L. Bell

I spent lot of my time during these months (as my annual report shows) to generalise the Principal Component Method (PCM) which describes the probability density function  $p(r,t)$  of rainfall 'r' with time 't', in a succinct way as the sum of a few (two or three) functions of the form  $p_{\alpha}(r) \times n_{\alpha}(t)$ .

The PCM including nonlinearity which was tested in August, is working very successfully for two and three modes, and now can be used for any data set of interest. We call this as Nonlinear Principal Component Method (NPCM) .

The  $n_{\alpha}(t)$  as time series has to be studied in order to make an assessment of how best these coefficients show the time scales involved in the data.

I would like to continue these studies in future in INDIA.

USRA Quarterly Technical Report  
July 1 to September 30, 1992

Dr. Glen E. Liston  
Task Number: 910-043

This quarter I completed a paper titled "Evaluating GCM Land Surface Hydrology Parameterizations by Computing River Discharges Using a Runoff Routing Model: Application to the Mississippi Basin", which presents the Runoff Routing Model I developed for use in validating General Circulation Model (GCM) land surface hydrology representations. The model routes GCM produced runoffs through regional and continental-scale basins, and generates river hydrographs throughout the coincident watersheds. This has provided a unique opportunity to compare and relate GCM land surface hydrology with actual hydrologic measurements. As part of this research effort, the paper I authored, "A Runoff Routing Model for Validating General Circulation Model Land Surface Hydrology Parameterizations", for presentation at the Conference on Hydroclimatology: Land-Surface/Atmosphere Interactions on Global and Regional Scales, January 17-22, 1993, was completed and submitted for publication.

In addition to my off-line GCM hydrology research, I have performed an analysis of the hydrologic output from a recent annual Goddard Laboratory for Atmospheres (GLA) GCM integration. Focussing on the Mississippi Basin, this work pointed to possible model incompatibilities with the initial soil moisture data set currently in use. To improve the soil moisture initial conditions used in the GCM, I developed an off-line scheme which computes initial soil moistures which are much more compatible with the current Simple Biosphere-GCM representation of soil hydrology. My GCM research using the Runoff Routing Model has also indicated a strong need for land surface hydrology parameterizations to account for the influence of subgrid-scale soil moisture variability on runoff. I have developed a scheme which accomplishes this, and implemented in the Simple Biosphere version of the GLA GCM.

I have also been working with a computational surface-boundary layer model. In September I presented a paper I authored, called "A Computational Model of Two-Phase, Turbulent Atmospheric Boundary Layers With Blowing Snow", at the International Glaciological Society, International Symposium on Snow and Snow-Related Problems, Nagaoka, Japan, 14-18 September, 1992. A second paper on this subject is called "A Two-Dimensional Computational Model of Turbulent Atmospheric Surface Flows with Drifting Snow", and has been accepted in the journal *Annals of Glaciology*. A third paper I authored titled "Application of the  $E - \epsilon$  Turbulence Closure Model to Separated Atmospheric Surface Layer Flows", was submitted to the journal *Boundary-Layer Meteorology*.

During the following quarter I will continue to explore methods by which to improve the representation of subgrid-scale processes within land surface hydrology parameterizations.

# Quarterly Report

## Universities Space Research Association

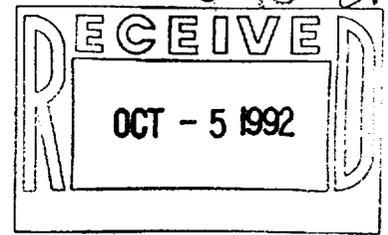
Joanna Joiner Noll  
Goddard Space Flight Center  
Code 910.4  
Greenbelt, MD 20770  
Task # 5000-147

October 16, 1992

This quarter I have continued my work on the AIRS/AMSU simulation and retrieval program. I have been able to show that it is possible to recover the emissivity as a function of frequency. Joel Susskind presented our results at the AIRS team meeting in September. Five teams performed retrievals on a simulated set of radiances known as the "write test". The best results were obtained using the algorithm developed by Joel Susskind and myself. Our collaboration with Frederique Cheruy and Alain Chedin produced the overall best results. Joel Susskind and I are currently revising a paper entitled "Determination of Temperature and Moisture Profiles in a Cloudy Atmosphere Using AIRS/AMSU" which was submitted to the proceedings of the High Spectral Resolution Infrared Remote Sensing for Earth's Weather and Climate Studies following a favorable review.

I have developed a surface temperature retrieval algorithm for the TOVS Pathfinder project. I have begun testing this algorithm using data from June, 1988. The initial results are encouraging. I have also been collaborating with Joe Otterman on several papers including a paper entitled "Surface-PBL Longwave Exchanges: A Comparative Parameterization for Bare and Vegetated Desert-Fringe Regions".

Next quarter, I will continue algorithm development and testing for both AIRS/AMSU and HIRS/MSU (Pathfinder). I will attend the AIRS team meeting in January at JPL in Pasadena. I will also give a seminar entitled "The Millimeter-wave Spectra of Jupiter" at the BIMA seminar series at the University of Maryland.



**To:** D. Holdridge  
**From:** G. Huffman  
**Re:** Quarterly report  
**Date:** October 1, 1992

Work on the Goddard Scattering Algorithm (estimation of precipitation from SSM/I microwave) focused on problems estimating precipitation over cold land and ice. Most of the changes I made to the algorithm were in the sense of masking off more areas as "not precipitating." In particular, a "reasonableness test" was imposed at higher latitudes to knock out unphysically high precipitation rates on a pixel-by-pixel basis.

During the quarter, final datasets were submitted to the Wetnet Precipitation Intercomparison Project 1. Also, I assisted Eric Nelkin (USRA summer student) and Andy Negri (912) in generating estimates for the Algorithm Intercomparison Project 2. This international algorithm intercomparison effort focused on data Great Britain in February, 1991, so the cold land problems mentioned above have been acute.

The first version of an oriented, non-symmetric smoother was developed and tested as a side project. It tends to have the desired properties, but generates spurious values in regions where the gradients change direction. Further development will probably start with a better derivative estimator.

The major project in the quarter was preparing for and attending the International Workshop on Analysis Methods of Precipitation on a Global Scale, 14-17 September, Koblenz, Germany, organized by the Global Precipitation Climatology Centre (GPCC). As described more fully in my trip report, the Workshop was intended to review the state of the art in producing global precipitation estimates and help GPCC decide how to merge estimates from different sources (gauges, satellites, and numerical models). Dr. R. Adler (912) was invited, but due to other commitments delegated the trip to me as the prime focus of the global SSM/I-IR combination project. My talk on "Global Precipitation Estimates Using Microwave and IR Data" was the only presentation to discuss the combination of data from different satellite (or any other) sensors, and a diagram developed by Dr. Adler and me formed the basis for the subsequent discussion on data merger.

Finally, we have started conversations with Dr. A. Chang (974) on comparing his SSM/I precipitation estimates with ours. The primary goal is to merge these estimates for GPCC-type activities.

One major issue arising from the GPCC workshop is the need for estimates of uncertainty. Some such estimate will be an important goal in the coming quarter. This effort will likely be associated with a project in our group to generate examples of merged precipitation estimates. We also need to continue examining the behavior of the Goddard Scattering Algorithm under various climatic conditions, as well as the smoothing/combination scheme. Finally, we have enough SSM/I data in a convenient format now that a year of data may be processed to give us a look at the algorithm over a complete annual cycle.

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During the quarter I prepared:

Huffman, G.J., R.F. Adler, P.R. Keehn, A.J. Negri, 1992: Examples of Global Rain Estimates from Combined Low-Orbit Microwave and Geosynchronous IR Data. 4<sup>th</sup> Symposium on Climate Change Studies, 17-22 Jan. 1993, Anaheim, CA.

Huffman, G.J., R.F. Adler, P.R. Keehn, A.J. Negri, 1992: Global Precipitation Estimates Microwave and IR Data. *Proc. of the Internat. Workshop on Analysis Methods of Precip. on a Global Scale*, 14-17 Sept. 1992, Koblenz, Germany, GPCP.

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Chung-Kyu Park  
Task number: 5000-150

October 30, 1992

## Quarterly Technical Report

*Work Period: July 1, 1992 - October 30, 1992*

### 1. Low-Frequency Waves in the Aries GCM

The heating experiments with the Aries GCM have been continued. The model response to the idealized tropical heating appears to be too complicated to identify the extratropical wave sources related to the extratropical forcing due to the nonlinearity of the full model. The model has been linearized to the climatological diabatic heating and tested for the sensitivity to the initial conditions. The integration of the linearized version of the model with different initial conditions raised an interesting question of the model behavior without the transient. The linearized version of the model provided a realistic patterns with the fixed zonal mean temperature. The tropical heating experiments are continued with this linearized model.

### 2. Future Research Plan

The future research plan includes (1) the heating experiments with the linearized version of the Aries GCM to examine the impact of the tropical heating on the extratropical stationary waves and (2) the diagnostics of the multi-year dataset simulated by the frozen version of GEOS-1 GCM.

### 3. Travel

I gave a summer special lecture at Pusan National University, Korea from July 27 to August 22, 1992.

October 20, 1992

To : USRA

From : Hye-Yeong Chun

Subject : USRA Quarterly Technical Report (July 1, 1992 - September 30, 1992)

Task Number : 910052

1. The surface pressure traces of Champaign and nearby area in Illinois for the wave event period of 5-6 January 1989 have been analyzed with an appropriate frequency filter. The detrended surface pressure indicates that the period of sharp pressure drop is about 10-12 minutes. This is consistent with the wavelength calculated from the weakly nonlinear solitary wave theory. Contrary to the other published study (Ramamurthy et al., 1990 *Nature*), using a lower frequency filter, the period of the wave in this case is much smaller than an hour.
2. The 50 MHz ST Doppler radar data observed at the Flatland Atmospheric Observatory located on the flat terrain of east-central Illinois have been analyzed. Again, the horizontal and vertical velocities are quite different based on the filtered frequency range. When we filter out fluctuation with less than 1.5 hr period, the streamline shows a single wave elevation with more than 4 km vertical displacement over 2-3 hrs. This is similar to what Ramamurthy et al had. However, when we use the band filter frequency range from 0.5 cph to 12 cph which corresponds to 2 hr to 5 min, the pattern of the streamlines is quite different. Based on the surface pressure trace, the filter frequency we used is appropriate. However, the large amplitude wave over long period is itself interesting even though this wave is not what is observed in surface pressure trace. Perhaps, the rotational effect should be included in order to consider that large wave.
3. The solitary wave solution is plugged into the 2-dimensional cloud model as the initial condition. Somehow, the simulated surface pressure is well matched with that of the solitary wave solution, except that the magnitude of the pressure perturbation from the numerical simulation is larger than that from the weakly nonlinear solitary wave theory.
4. In the next quarter period, I will include the rotational effect in the weakly nonlinear solitary wave theory. The weakly nonlinear solitary wave solution including rotation can be applied to several wave events observed with a large wavelength ( $> 1000$  km) over long period.

910-052

USRA QUARTERLY TECHNICAL REPORT  
JULY 1 - SEPTEMBER 30, 1992

Dr. John R. Scala  
Task # 910-055

I participated in the third International Cloud Modeling Workshop, held in Toronto, Canada, 10-14 August 1992. The meeting was held in conjunction with the WMO Workshop on Cloud Microphysics and Applications to Global Change. I co-chaired the session on mixed-phase Spring/Summer convective clouds. I presented a paper entitled "Two-dimensional simulations of mixed-phase convective clouds: 28 June 1989 NDTP case", and assisted in the coordination of discussions and in the assimilation of results from the session. I presented the group's findings and recommendations for future modeling efforts to the cloud modeling workshop, and to a joint gathering of participants from both workshops on the final day. We found several similarities in the simulations, particularly: 1) a strong relationship between autoconversion and increased hail production, 2) the shedding of hail as the major source of precipitation, 3) a "seeder-feeder" mechanism for hail growth, and 4) strongly overshooting tops associated with peak vertical velocities exceeding  $40 \text{ ms}^{-1}$ . A report of the principle findings of our subgroup is due by 31 October. In addition, I plan to submit a manuscript to the *Journal of Applied Meteorology* that addresses the effect of different initialization schemes on the simulation results of the 28 June NDTP case.

Following the Toronto meeting, I attended the Eleventh International Conference on Clouds and Precipitation, held in Montreal, Canada, 17-21 August 1992. The forum provided an ideal format for the exchange of scientific ideas, and the renewal of professional associations. I discussed last year's CaPE experiment with two of the program's principle investigators: Dr. Barnes of the University of Hawaii, and Dr. Fankhauser of NCAR, and the role of convection in the tropospheric transport of trace gases with Drs. Alheit and Hauf of the Institute of Atmospheric Physics in Germany.

I talked with Dr. Stith of the University of North Dakota and with Dr. Orville of the South Dakota School of Mines and Technology about the upcoming North Dakota Tracer Experiment (NDTE), scheduled for June-July 1993. Both scientists participated in the North Dakota Thunderstorm Project (NDTP), and will be actively involved in next summer's NDTE. Dr. Stith has invited me to come to the University of North Dakota to work with him on several NDTP data sets, and to discuss a strategy for NDTE. I expect to attend a planning meeting early next year to address NDTE field operations.

A preprint paper entitled "Convective transport and mixing of tracers by midlatitude squall-type mesoscale convective systems", authored by J.R. Scala, K.E. Pickering, W.-

K. Tao, J. Simpson, and R.R. Dickerson, was submitted for inclusion in the conference volume of the Special Session on Atmospheric Chemistry at the 73rd Annual Meeting of the AMS. The meeting is scheduled for January 17-22, 1993 in Anaheim, CA. A special issue of the *Journal of Applied Meteorology* is planned for the papers presented in this special session.

The impact of organized mesoscale convection (observed in two recent field programs) on the transport and subsequent photochemical production of ozone is currently under investigation with colleagues in the Atmospheric Chemistry and Dynamics Branch at GSFC, and Prof R. R. Dickerson of the University of Maryland. The study includes storms from OK PRE-STORM (Oklahoma-Kansas Preliminary Regional Experiment for STORM-Central), and the NDTP.

I participated in a workshop held recently at NASA/Goddard Space Flight Center on 30-31 July 1992. The purpose of the meeting was to design a coupled meteorological-chemical experiment to address the convective transport of ozone precursors. I presented my current research to the working group, and assisted in the composition of a "white paper" that will be presented to the GTE Advisory Committee meeting in November. The primary goal is to link the proposed study to a major field program with the most appropriate suite of meteorological and chemical instrumentation. I am completing the animation of several 3-D tracer fields to further emphasize the importance of clouds as deep tropospheric transporting agents. A videotape of the animation will be shown at NASA headquarters during the November meeting.

I performed the following professional duties during the last quarter: 1) selected by the editors of the *Journal of Geophysical Research-Atmospheres* to determine the suitability of a submitted manuscript for publication, and 2) represented the convective-scale modeling group as a member of the GEMPAK committee of the Severe Storms Branch.

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## TECHNICAL REPORT: 1st July 1992 – 30th September 1992

Ranga B. Myneni  
Task Number 5000-202

1. A research paper *Synergistic use of optical and microwave data for agrometeorological applications* was submitted for publication in *Advances In Space Research*.
2. A research paper titled *Atmospheric Effects in the Remote Sensing of Surface Albedo and Radiation Absorption by Vegetation Canopies* was submitted to *Remote Sensing Reviews*.
3. A research paper titled *Radiative Transfer in three dimensional atmosphere-vegetation media* was submitted for publication in *Journal of Quantitative Spectroscopy and Radiative Transfer*.
4. I gave an invited talk at the 1992 World Space Congress in Washington, DC, in late August.
5. A research paper titled *Simulation of space measurements of vegetation bidirectional reflectance functions* was accepted for publication in *Remote Sensing Reviews*.
6. I advised this summer a graduate student, Mr. Jeff Privette, and collaborated on research on inverting physically based models through merit function minimization for the estimation of surface state variables. This work will be submitted for publication soon. Mr. Privette is PhD student from the University of Colorado in the department of Aerospace Eng. with Prof. Bill Emery.
7. I am currently working on using artificial neural networks for the inversion of vegetation radiation transport models.

01 July                      September  
 Quarterly Report: ~~31 March~~ 1992 to 30 June 1992

Gregg Bluth, USRA/Goddard Research Associate

Task # 920-004

My main research goals this past year have been to complete our inventory of TOMS data for publication, and find ways to validate our measurements. With regards to completing the TOMS inventory one of the major obstacles has been overcome: that of standardizing just how we measure and define an eruption cloud. Depending on latitude, season, eruption size, local weather conditions, current instrument conditions, and investigator there were many possible interpretations of the extent and size of an erupted SO<sub>2</sub> cloud, which made it difficult to make intercomparisons of our data. I am now able to use virtually the same method to evaluate each eruption. We are also cataloguing each eruption and storing images and processed data as part of a project with with the Earth Observing System team. With access to National Meteorologic Center wind data, I am also able to estimate SO<sub>2</sub> cloud heights to determine whether they reached stratospheric or tropospheric levels.

On July 23-24, I attended the Earth Observing System (EOS) Plume meeting held at Goddard. I gave a presentation of some recent TOMS results.

From July 6-24 I was mentor to Eleni Roumel under the National Space Club Scholars program. She worked on a project with me using information from Dr. Tom Simkin of the Smithsonian Institution global Volcanism Program. She looked for satellite evidence of a large eruption of Fernandina caldera, Galapagos, discovered by Simkin in the field. The only clues he could give us was that the eruption occurred sometime between late 1980 and early 1982. Eleni and I searched through the TOMS database, and were able to confirm that no large emissions of sulfur dioxide had accompanied the eruption.

The following papers have either been presented or submitted:

Kump, L.R., G.J.S. Bluth, M. Gibbs, and E.J. Barron (1992) The role of paleogeology in CO<sub>2</sub>-induced climate change. International Geologic Congress August 25-28, 1992, Japan.

Bluth, G.J.S., A. J. Krueger, C.J. Scott, L.S. Walter, and C.C. Schnetzler (1992) SO<sub>2</sub> Cloud Tracking from the June 27 Eruption of Mount Spurr, Alaska. American Geophysical Union meeting December 7-11, 1992, San Francisco, CA.

Schnetzler, C.C., G.J.S. Bluth, A. J. Krueger, L.S. Walter, and S.D. Doiron (1992) A sulfur emission index (SEI) for explosive volcanic eruptions. American Geophysical Union meeting December 7-11, 1991, San Francisco, CA.

I submitted a proposal to NASA headquarters in response to a "Dear Colleague" letter. The general topic is understanding and quantifying the role of sulfate and other aerosols in the troposphere:

"Contribution of Volcanic Activity to the Atmospheric Sulfur Dioxide Budget", submitted with Co-Investigators Dr. A.J. Krueger (Code 916) and Dr. L.S. Walter (Code 900).

TO: Denise Dunn, Administrative Assistant  
FROM: Carol A. Russell  
DATE: 10/23/92

SUBJECT: Technical Report for 1 July through 30 September 1992  
Task Number: 920-012

PROJECT REVIEW:

The task I am working on involves a number of projects, all related to the Advanced Solid-state Array Spectroradiometer (ASAS), an airborne imaging sensor operated by the Lab for Terrestrial Physics.

I. FIFE data analysis

ASAS data acquired during FIFE will be used to estimate absorbed photosynthetically active radiation (APAR), hemispherical reflectance (RH), vegetation indices, and other biophysical parameters. Given the ASAS instrument's spectral and bidirectional (off-nadir) capabilities, it is believed the results should improve such estimations.

The above work can only be achieved by using atmospherically corrected radiance values. Atmospheric correction is one of the most important objectives challenging the remote sensing community, and it is critical to the analyses of ASAS data. Consequently, a major part of this work will involve the testing, evaluation, and modification of existing atmospheric correction algorithms on ASAS data. It is hoped that this process will lead to such corrections becoming incorporated feasibly into a routine data processing sequence.

Initial analyses of FIFE data will be limited to homogeneous training areas, and the results will be checked for accuracy using coincident FIFE datasets, available from the FIFE Information System database. Once procedures have been developed and assessed at this level, subsequent work will apply the routines to larger areas, and ultimately include entire images. Variability due to scale differences will be assessed.

A number of procedures for calculating biophysical parameters exist in the literature. These will not be described here, but will be explained in future technical reports as they are used and evaluated.

II. Data Acquisition Missions

The ASAS instrument typically participates in several field campaigns from late spring through early fall each year. I have experience in operating the instrument and locating sites, and may occasionally be required to assist in the collection of ASAS data.

III. Evaluation of Sensor Performance

A new spectral array was just recently installed in the instrument which will be undergoing substantial testing and evaluation. I will be assisting engineers and programmers in these efforts with the objective being to optimize the value of ASAS data for scientific utility.

IV. Interaction with Scientific Community

The ASAS Principal Investigator and I would like to hold a Symposium and workshop dedicated to the use of ASAS data. This would be the first time ASAS users would be assembled together for this purpose. The appropriate forum for these will be determined.

Currently, I also serve as a point of contact for requests of ASAS data that are not accessible through other databases.

#### PROGRESS:

The bulk of work accomplished has been on the Fife Data Analysis topic, since I plan on attending a FIFE workshop in November and will present some results there.

#### I. Fife Data Analysis

Initial inventory and identification of appropriate datasets have been completed. This involved surveying FIS for lightbar data and comparing collection times with archived ASAS data. Eighteen ASAS site passes exist that are sufficiently concurrent with UNL and KSU lightbar measurements for further analysis.

C-130B flight navigation data corresponding to the identified ASAS site passes has been acquired and brought online. Navigation data is essential for establishing correct view and solar geometries relative to a given site.

A meeting was held with several Univ. of Maryland researchers who are collaborating on aspects of the FIFE study and GSFC personnel familiar with the 6S atmospheric correction code, with the goal being to decide upon appropriate input parameters to the correction model.

Mapping of specific training areas onto site photos/overlays has been completed, and selection of these training areas from actual image data has begun.

#### II. Data Acquisition Missions

Not applicable at this time.

#### III. Evaluation of Sensor Performance

Viewed several images produced by the new array to assist in the site identification and discrimination of "slew" data.

#### IV. Interaction with Scientific Community

Provided Dr. Dorothy Hall of GSFC with ASAS data collected over Glacier National Park, Montana.

In addition to the above projects, I submitted an abstract to the Annual Meeting of the Geological Society of America, which was accepted.

#### PLANNED WORK FOR NEXT QUARTER:

Continue selection of small training areas from ASAS images. Atmospherically correct the radiance values obtained from the training areas.

Learn IDL (Interactive Data Language) and create an IDL program to plot 3-D diagrams of radiance values versus spectral band versus view angle.

Compare plotted results with ground and helicopter data.

Attend FIFE workshop and present above plots and comparisons.

Attend Annual GSA meeting in Cincinnati and present talk on dissertation work.

## TECHNICAL REPORT

FOR THE TERM FROM JULY 1 TO SEPTEMBER 30, 1992

**MAKOTO SATAKE**

TASK NUMBER 930-008  
USRA VISITING SCIENTIST PROGRAM  
CODE 936, NASA / GODDARD SPACE FLIGHT CENTER

OCTOBER 1, 1992

### OVERVIEW

Relating to development of the TRMM -Tropical Rainfall Measuring Mission- Science Data and Information System (TSDIS), topics of my activities in this term include: TRMM related meetings; Input of the airborne radar algorithms into the TSDIS prototype system; and Learning the prototype. As to study on data processing of rain radar data, I have concentrated on study of rain profiling methods. In addition to those two regular activities, I attended a conference on clouds and precipitation held in the August, in Montreal.

### DEVELOPMENT OF TRMM SCIENCE DATA AND INFORMATION SYSTEM (TSDIS)

Along with regular TSDIS meetings, there were some important (non-regular) TRMM related meetings which I attended (in part, some of them), TSDIS Prototype PDR on July 8, TRMM PDR on July 15 to 17, and NASA/NASDA programmatic meeting on July 20 to 22.

I have provided the information, when something in the meetings is considered necessary to them, to my colleagues in CRL, Japan who is engaged in developing the TRMM radar.

Airborne radar algorithms and data provided by Dr.Meneghini (and other TRMM Radar Team members) were inputted to the TSDIS prototype system so as to be used as a model of TRMM radar algorithms and data. Although I wasn't directly involved in this input, I have been concerned with the airborne radar algorithms, as well as TRMM radar algorithms. I am, therefore, very interested in how they work in the prototype system.

I started to learn the TSDIS prototype system, not only its design but how it works (and how to use it). It will hopefully enable me to test connectivity and accessibility of the TSDIS from Japan. That test will be a must before the TSDIS becomes operational.

Since the TSDIS prototype system is under development of its earliest practical version, I have just begun the study by reading a textbook of *unix* on which the system will be operated.

### RAIN RADAR DATA PROCESSING

I have focused on study of rain profiling methods from radar data. There are several methods proposed to retrieve rain rates at each radar range bins from radar signals (backscattering echoes from raindrops) which suffered attenuation during propagating in the rainfall. Among them are methods proposed by Drs.Fujita, Kozu, and Meneghini, each.

My current interest is to examine whether the Fujita's method is applicable to actual airborne radar data and hopefully to space borne radar data.

I applied the method to the NASA/CRL T-39 airborne radar data (X- and Ka-band) taken in the CaPE experiment (in Florida, summer 1991), and got the result of retrieved rain rates for a few cases of rainfalls. I talked on the results with Dr.Iguchi who also had been studying rainfall profiling methods.

### ATTENDING ICCP-92

I attended the 11th International Conference on Clouds and Precipitation (ICCP), on August 17 to 21, 1992, at McGill University, Montreal, Canada. ICCP is held every 4 years with a cooperating organization of American Meteorological Society. The 11th ICCP consisted of ~350 papers presented, with ~450 participants from over 30 countries. Its technical areas covered from 'Cloud Microphysics', 'Precipitation Physics', and 'Instrumentation' to 'Remote Sensing of Clouds and Precipitation (including Satellite Observations)'.

Being at the conference, I learned about some of the presented papers - my main interest was on studies and measurements of precipitation - which included several papers relating TRMM presented by the scientists from GSFC and JPL. I could exchange some useful information relating to my task, having discussion with some participants, particularly a person of the McGill Univ. who knew know-how of the Patric Air Force Base (Florida) radar.

### PLAN FOR THE NEXT TERM

In the next term of October to December, respecting the TSDIS prototype development, I am going to learn the prototype system which is to be completed its phase 1 stage by the end of December.

I am planning to finish my rain profiling study, making a report.

## Quarterly Report for Kevin Olson, Task 930-015

### 1 Work in Progress

My research for the period 1 July - 30 September has been focused in several areas. As I described in the last quarterly report, I have written a computer code to do gravitational N-body problems. I also described how I hope to use this code to study problems in the dynamics and star forming properties of interacting/merging galaxies. The code was written in APPL (Applications Portable Parallel Library) to run across our distributed network of workstations and I discussed that I planned to port the code to two available MIMD supercomputers, the Intel DELTA at Caltech and the Intel iPSC/860 at NASA/Ames.

The code was easily ported to both of these machines and APPL worked well on each. Several problems were encountered, however. The code, as originally written, took too much memory per processor to run. Therefore, revisions needed to be made. The code has now been revised and is working on the DELTA. A further problem is that the code is not as efficient as one would like. In fact, the code running across four workstations, executes faster than the same code running across four processors of the DELTA. The problem is the i860 processing chip upon which these machines are based. The i860 has a relatively small memory cache and it is difficult to write code to make efficient use of it. This is compounded by the fact that the fortran compiler does not produce good machine code to take advantage of all the features of the i860 chip. My code is particularly problematic in this regard in that it makes liberal use of pointers. However, the code does scale well with the number of processors and near linear speedups are obtained. Work is continuing in this area to make the code execute as fast as possible for the largest number of bodies possible.

In the past quarter I have also begun to write a similar code to that described above, for the Maspar here at Goddard. The Maspar is a SIMD (single instruction, multiple data) machine with 16,384 processors, and hence has a different architecture than the machines mentioned above. This project has only recently been initiated and a more definitive assessment of the Maspar for this problem is not possible at this time.

In my last report, I also stated that I would write a code to simulate gas dynamics using a technique known as smooth particle hydrodynamics. This is a lagrangian technique and the motions of particles are followed through space. Each particle carries with it local values of the gas pressure, temperature and density, from which the forces on other particles are computed. A one dimensional version of this code has been written and currently runs on my workstation and has been applied to several simple problems (eg. colliding streams of gas). Also, this code has been ported to the Maspar by rewriting the code in Fortran 90.

In the last quarter I also collaborated with Dr. Clark Mobarrry in mentoring Ted Yang for the VSEP program. Ted worked on a problem which is of interest to me, namely interacting galaxies. He wrote a code for the Maspar which simulates the interaction of two disk galaxies by using the restricted three body approximation (the mass of each galaxy is assumed to be concentrated at a point in its center and the stars orbiting this mass center are assumed to move as test particles). As result of this, Ted produced a video animation of some of his results which he displayed at his presentation following the completion of the program.

## 2 Work Planned for Next Quarter

1) I plan to continue to work on the N-body code I have written for the Intel machines. The code must be made more efficient (by at least a factor of ten). It is my goal to have the code be able to sum the gravitational forces between 1 million particles in small amount of time (less than 20 seconds). Whether this will be possible remains to be seen. I am confident that performance of this can be achieved, since the major loops in the existing code have not yet been vectorized. Also, several algorithmic changes are presently being investigated for their potential to improve the performance of the code. Also, Caltech will obtain an Intel Paragon computer which will aide in achieving this goal.

This code, once completed and fully optimized, will be applied to problems in the dynamics of interacting galaxies. I hope to address the question of bar formation in a galaxy as a result of its interaction with another galaxy. N-body codes have shown that bars can form as a result of the interaction of two galaxies. However, the number of simulations which addresses this questions is small. With my code I hope to perform a larger search of parameter space (eg. the inclination of the two galaxies, their distance of closest approach, their relative velocity, their internal mass distribution, and their relative mass).

2) I also plan to continue my work on producing a gravitational N-body code for the Maspar in Fortran 90.

3) I hope also to extend the SPH code I have written to multiple dimensions and to test it on some real problems. I also hope to add magnetic effects to the existing code so that problems in MHD can also be studied. Ultimately the SPH code will be combined with the gravitational N-body code described above. If this is accomplished, the code will be used in the study of the dynamics of giant molecular clouds in an effort to understand their structure, their interactions through collisions, and, I hope, to learn something about the processes which lead to star formation.

4) The research projects for the HPCC have now been selected. I anticipate that in the upcoming quarter I will begin to work with these researchers in porting their codes to some of the parallel machines that are available.

1995 9 1985

**Technical Report for 1 July thru 30 September 1992****Bruce Fryxell**

Much of my work during this quarter has involved writing a chapter for a book on computational methods for astrophysics. My chapter will describe the Piecewise-Parabolic Method for computational gas dynamics. This method has much higher resolution than most numerical schemes in use today, but is very complex and requires a significant effort to program. A floppy disk containing the FORTRAN source code of the program will accompany the book. As a result, this high-resolution method will become easily accessible to a much wider range of researchers, which should significantly improve the quality of research in computational astrophysics.

This algorithm is ideally suited to massively parallel machines and extremely high performance is expected. This, coupled with the high-resolution of the method, should make it possible to solve new classes of problems which are beyond the capabilities of simpler algorithms and serial computers. Work has already begun on adapting the code for use on the Maspar computer at Goddard.

I have also begun work on developing a Magneto-Hydrodynamic code based on the same numerical techniques. Including magnetic fields increases the complexity of the algorithm enormously but is necessary for solving many problems in astrophysics and space physics. There are two separate groups already working on this problem. One is led by Phil Colella at the University of California at Berkeley. I traveled to California to visit him during this quarter and have started a collaborative effort on this project. The other group is led by Paul Woodward at the University of Minnesota. He has also agreed to collaborate with me on this project. I intend to examine these two approaches and combine the best features of each into my code. I expect this to be a long term project which will continue for a year or more.

Another project in which I am involved is the calculation of the supernova mechanism in massive stars. Current one-dimensional models of supernovae fail to explode. Adam Burrows at the University of Arizona and I are calculating multi-dimensional effects which may lead to an explosion. The neutron star formed in the initial collapse of the core of the star is unstable to convective overturn. This will lead to a non-spherical flux of neutrinos being emitted from the young neutron star. Preliminary results have shown that the amount of non-sphericity is much higher than was predicted, and this could have significant consequences. We have written a paper describing these results which is being published in Science in October.

During the next quarter I plan to finish the chapter for the computational methods

book which I am writing. The first draft is already complete, and only minor modifications are required. I also expect to finish modifying my code for use on the Maspar computer, and if all goes well, to begin doing some high-resolution simulations on astrophysics problems. Work will also continue on the development of the magneto-hydrodynamic code. A trip to the University of Minnesota is planned to begin working with Paul Woodward on this project.

**QUARTERLY REPORT FOR J. ANTHONY GUALTIERI**

July 1, 1992 - September 30, 1992

Associate Research Scientist, Universities Space Research Association

Computer Systems Research Facility, Code 935

**RESEARCH SYNOPSIS:****Inversion Algorithms:**

**AIRS** A neural network backpropagation code was developed on the Maspar SIMD computer using the the Maspar linear algebra math library. This code will allow very large networks with large training sets appropriate to the AIRS retrieval problem to run at very high speeds. First results show the network running at six million connection updates per second - to be compared to a quarter million connection updates per second on a DEC5000 serial machine. With optimization I believe this speed could be improved by a factor of two to three more.

**GLA** I have continued to attend Joel Susskind's group meetings in Code 911.

**Collaboration with Prof. Howard Motteler** We have worked together to prepare data sets for the HIRS and AIRS instruments using the TIGR data sets from JPL.

**Distance Between Images:**

Together with Jaqueline Le Moigne, NRC Associate of code 936 and Charles Packer of Code 935 some further applications on this algorithm to image registration and fingerprint differentiation were conducted. This work will be included in the presentation at the Frontiers 92 symposium.

**VSEP**

I was mentor for VSEP student Lukasz Zielinski and we studied using formal inversion of feedforward neural networks to solve an inversion problem. He prepared a report that was submitted to VSEP.

**WORK PLANNED FOR NEXT QUARTER:**

**TOVS Pathfinder** Assist Susskind's group in converting their pathfinder products into HDF format for inclusion into the Goddard DAAC. Construct a fast forward code for the SSU instrument for inclusion into Susskind's retrieval algorithm for the TOVS pathfinder.

**Inversion Algorithms:**

Prof. Howard Motteler, NRC RRA, will further adapt the neural network back propogation code I have developed on the Maspar and adapting it to the atmospheric inversion problem.

**PUBLICATIONS**

None this quarter.

**TRAVEL**

None this quarter.

Quarterly Technical Report of Toshio Iguchi  
for the period of July-September, 1992

In this quarterly period, I wrote a program that calculates the double scattered radar return from Raleigh particles. The purpose of this calculation is to find out whether the rather high linear depolarization ratios (LDRs) observed at Ka-band in CaPE experiment are due to the multiple scattering effect or not. I think it is a multiple scattering effect and would like to confirm it.

I spent the latter half of the quarter period for the preparation of my talk at TRMM radar team meeting which is to be held on October 5-9. The major part of the work was the review of the existing rain retrieval algorithms for a space-borne radar. I also tested these algorithms with the CaPE data using the program I developed in the previous quarterly period.

In the next quarterly period, I will summarize the results of double scattering calculation and the comparison of rain retrieval algorithms. I also plan to calculate the drop size distribution over a rain storm in the CaPE data and see how the distribution varies. This would be a topic of paper I might submit to the Radar conference next year. I will also continue working with Mr. R. Meneghini on the modification of CRL air-borne radar to a ground-based radar at Wallops island.

SCA

# QUARTERLY TECHNICAL REPORT

1 July to 30 September 1992

by

Chaing Chen

*Universities Space Research Association  
NASA/Goddard Space Flight Center  
Greenbelt, MD 20771*

## Summary of accomplishments

1) During this period, Dr. Chen continued to work on the study of the pressure gradient force (PGF) problems over a steeply sloped terrain. The conventional wisdoms to reduce the PGF error in a hydrostatic model are to limit the slope of the terrain to less than 5% ( $\Delta h/\Delta x < 5\%$ ) or to use larger  $\Delta z$  such that the slope of the grid box is larger than that of the terrain slope ( $\Delta z/\Delta x > \Delta h/\Delta x$ , Mahrer 1984). Numerous experiments were conducted to examine these criteria. It is found the criterion ( $\Delta z/\Delta x > \Delta h/\Delta x$ ) is valid only when the slope of the mountain is greater than 5% and a stably stratified layer is located near the upper part of the mountain. On the other hand, the PGF produces small error when a uniform stratified layer is used in the simulation. The sharp change of stratification near the peak of the mountain is the main contributor of the PGF errors.

2) A major effort devoted during this period is to assist DRS. Koch and Karyampudi to conduct numerical experiments to simulate the generation and the propagation of an undular bore on the lee side of the mountain using Dr. Chen's non-hydrostatic model. We have found that the numerical model is a very useful tool in this research. For instance from the numerical experiments, we learned that the cold pool at the upstream of

the mountain is an essential condition to generate bore at the downstream side. We also learned the curvature effect associated with the low-level easterly jet is very important to maintain the strength of bore while the bore is propagating hundreds of kilometers in the downstream direction.

3) As a part of the effort to develop a future mesoscale nonhydrostatic model, Dr. Chen spent some time to review the unstructured grid method, in which the idea is inspired by the seminar given by Dr. Bacon of SAIC. Dr. Chen feel that the unstructured grid method can be a very powerful tool in the mesoscale research, especially to deal with the scale interaction processes.

see:

Nolan Associates  
4400 Robertson Blvd.  
Alexandria, VA 22309  
(703) 780 1938

October 26, 1992

Universities Space Research Association  
Visiting Scientist program  
Mail Code 610.3  
NASA/Goddard Space Flight research Center  
Greenbelt, MD 20771

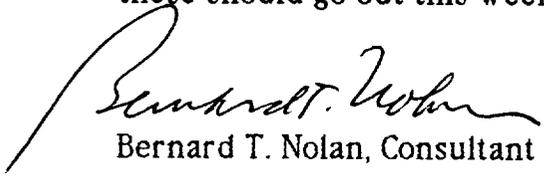
Technical Activites Report No. 9-September 24 thru Octboer 23, 1992

Dates of Effort-September 25,29, October 1,5,7,16,19 and 22, 1992

On September 29 I met with representatives of the TOGA-COARE International Project Office (TCIPO) and members of the NASA field operations team to resolve issues relating to the allocation of space in Townsville and several logistics issues. Originally planned for two days, the meeting with the TCIPO people took half a day. During the afternoon of the 29th I met with the two other NASA operations coordinators (who will be in Townsville sequentially) to work out details for the completion of Section 5.0 of the mission plan dealing with mission operations and coordination. A report covering the outcome of this meeting was prepared and submitted to Dr. Theon on October 5th.

Section 5.0 of the mission plan was completed and incorporated into the document by mid October along with changes to other sections. A fresh copy of the plan was generated and is currently under review by Drs. Kakar and Suttles and myself.

Plans are going forward for a final mission readiness review in mid December. I have prepared an agenda for the review and the cover letter; these should go out this week.

  
Bernard T. Nolan, Consultant

Nolan Associates  
4400 Robertson Blvd.  
Alexandria, VA 22309  
(703) 780 1938  
September 25, 1992

Universities Space Research Association  
Visiting Scientist program  
Mail Code 610.3  
NASA/Goddard Space Flight research Center  
Greenbelt, MD 20771

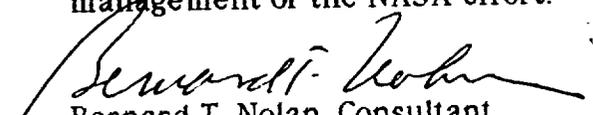
Technical Activities Report-June 29 through July 24, 1992

Dates of Effort-August 28,31, September 3,4,8,9,10,11,14,15,17,21,22, and 24  
1992

Major activity during this period focused on follow up work in connection with the NASA TOGA COARE readiness review conducted August 26 and revisions to the NASA T-C Mission Plan. With regard to the latter, two additional draft revisions have been prepared and edited since the second draft was published and sent out for comment in July. The current version, labeled final draft, is nearing completion and will be distributed to a much smaller contingent of reviewers by mid October. The final draft must be in position before the end of November. I have written several sections of the plan and am collaborating now on a section dealing with field management, operations and logistics. I am also serving as principal editor.

Logistics arrangements for the deployment phase of T-C are entering the final planning stage. I will join a team of NASA operations coordinators in Boulder, CO on September 29 and 30 to work out details with the T-C International Project Office.

On September 3 and 4 I met with Dr. J. T. Suttles, NASA Headquarters, D. McDougal, Langley Research Center and F. Valladares of Science Applications International Corp. in Hampton, VA to discuss support arrangements for publishing the mission plan and also for the January-February 1993 on site management of the NASA effort.

  
Bernard T. Nolan, Consultant

BRUTON B. SCHARDT  
QUARTERLY REPORT  
JULY-SEPTEMBER 1992

Major activity during this quarter involved the sorting of documents and records for the move to the new NASA building. Correspondence and other records pertaining to the Landsat, Large Format Camera and Shuttle Imaging Radar programs as well as miscellaneous documents were either packed for moving, identified for archives or destroyed. The move took place the end of July and the following week the process of unpacking and refileing began. Also involved during this period was the review and selection of LFC 35mm slides with Dr Greer for his presentation to the International Society of Photogrammetry and Remote Sensing Congress. A meeting was also held with Fred Engle and Priscilla Strain of the National Air And Space Museum to review their new publication "Looking At Earth", and to discuss preliminary arrangements for transfer of the LFC from NASA storage to the Air and Space Museum in accordance with recommendations from the General Accounting Office. Another activity in this period was the identification of a piece of LFC support structure hardware that had been discovered at JSC and should have been transported to the Stennis Space Center for storage with the LFC.

  
BRUTON B. SCHARDT

BRUTON B. SCHARDT  
MONTHLY REPORT  
AUGUST 1992

During this period I was involved in the review and selection of Large Format Camera (LFC) slides with Dr Greer of the Forestry Service for his presentation to the International Society of Photogrammetry and Remote Sensing (ISPRS) Congress. I attended part of this Congress to meet with Eastman Kodak representatives to view their display of a 5 by 14 ft enlargement of a color infrared LFC frame of the Great Barrier Reef. I had assisted Kodak in getting the LFC contact prints for this enlargement and also in getting NASA permission to use the LFC data. Also involved this month was a meeting with Fred Engle and Priscilla Strain of the Air and Space Museum to review their new book "Looking At Earth" which has just been published. This book contains many spectacular photographs including Landsat and LFC imagery. Other activities included making arrangements for reproduction of the slides finally selected for Dr Greer's presentation for use in other presentations on the capabilities of space photography.

*Bruton B. Schardt*  
BRUTON B. SCHARDT

97-107



BRUTON B. SCHARDT  
MONTHLY REPORT  
SEPTEMBER 1992

During the first ten days of this month activities involved identifying the hardware found at JSC that they believed belonged to the Large Format Camera. This was verified by Shuttle cargo bay photographs as being part of the Multi-Purpose Experiment Support Structure designed to support the LFC in flight. It was part of the LFC ancillary equipment that should have been sent to the Stennis Space Center for storage with the LFC. Also involved during this period was an initial quality review of the LFC 35 mm slides that had been reproduced for Dr. Greer of the Forestry Service, and review and comment on a General Accounting Office fact sheet on the Landsat Program. During the latter part of this month I was out of the area on personal travel.

  
BRUTON B. SCHARDT

USRA NAS 5-30442  
Activity # 270-007 Task I

Dr William W. Vaughan

Period 1 June 1992 - 20 August 1992

During this period efforts regarding the Statement of work were primarily devoted to the following activities and related services:

- 1) Background research and information development and consultation with NASA Technical Monitor on Technical inputs for accomplishment of activities related to task statement of work.
- 2) Collaboration with Dr John Thoen NASA HQ on preparation of final paper for publication in "The NASA Earth Observation Review: Remote Sensing From Space". This included interaction on development of outline and text including final preparation of graphical and table information and text for completed paper to be published in Rio de Janeiro Global Forum proceedings. The original and copies here

been provided to the NASSR  
Technical Monitor & Thera and are  
available upon request

- 3) The above efforts involved extensive  
interaction and mutual review on development  
of text and associated reports including  
service necessary to meet schedule. Some  
information developed during the research  
activities was brought to attention  
of Technical Monitor on an ad hoc  
basis for consideration in NASSR  
research program activities related to  
the SCA.

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USRA NAS5-30442  
Activity 970-007

Dr. William W. Vaughan

Period 1 August 1992 - 30 September 1992

During this period principal efforts were devoted to the following activities:

1. Reviews of committee charters and proposed standards task scopes relative to follow-up actions from Standards Technical Council Meeting.
2. Preparations for November Standards Technical Council and Standards Executive Council Meetings relative to agendas and issues for discussion/action.
3. Reviews of technical items relevant to NASA Atmosphere Research Program and interaction with NSA Technical Monitor.
4. Preparation of comments and suggestions on draft documents prior to finalization and approval for standards program publication.

970-007  
Task I

USRA NAS5-30442  
Activity 970-007 Task I

Dr. William W. Vaughan

Period 15 August 1992 - 30 September 1992

During this period efforts regarding the statement of work were devoted to the following activities and related series:

1. Completed follow-up actions on the final publication and distribution of the paper "NASA Earth Observation Program: Remote Sensing from Space" including interactions with the NASA Technical Monitor.
2. Provided detailed reviews and developed inputs relative to presentation of paper entitled "The Tropical Rainfall Measuring Mission" presented at the COSPAR Multi - Sensor Symposium held in Washington, D.C. September 1992. Based on presentation feed backs and inputs from NASA Technical Monitor, accomplished detailed analysis of material and prepared final graphical material, tables and text for publication as part of the proceeding of Symposium. The original and copies are being provided to the NASA Technical Monitor and are available upon request.
3. The above involved extensive interaction with NASA Technical Monitor, reviews and development of material, including supporting services, necessary to meet schedules, etc. Allied topics having potential value to NASA research program activities related to the SOW were brought to the NASA Technical Monitor's attention.

Technical Report of activities  
(1 July to 30 September 1992)

Employee: Brad S. Ferrier  
Date: October 20, 1992

Task Number: 920-005

Over eighty percent of my time during this quarter was devoted to writing the first in a series of two or three papers on the development of a new ice-phase parameterization and its performance in simulating convective storms in different large-scale environments. This first paper is a comprehensive description of the new, four-class ice microphysical scheme (4ICE) that I developed. This was a challenging effort because the parameterization is very mathematical and involves ninety distinct microphysical processes associated with calculating changes in the mixing ratios and number concentrations of four different ice species (cloud ice crystals, snow, graupel and frozen drops/hail), as well as the mixing ratios of liquid water on wet precipitation ice (snow, graupel, frozen drops). Additional improvements to the 4ICE scheme in comparison to other microphysical parameterizations were made in the following areas: (1) representing small ice crystals with non-zero terminal fall velocities and dispersive size distributions, (2) accurate and computationally efficient calculations of precipitation collection processes, (3) reformulating the collection equation to prevent unrealistically large accretion rates, (4) more realistic conversion by riming between different classes of precipitation ice, (5) preventing unrealistically large rates of raindrop freezing and freezing of liquid water on ice, (6) detailed treatment of various rime-splintering ice multiplication mechanisms, (7) a simple scheme for the Hobbs-Rangno ice enhancement process, (8) aggregation of small ice crystals and snow, and (9) allowing explicit competition between cloud water condensation and ice deposition rates rather than using saturation adjustment techniques. A major conclusion of the paper is that it is more important to preserve the spectral widths of the particle distributions rather than conserve particle number concentration when representing changes in ice number concentrations due to melting, vapor transfer processes, and conversion between different hydrometeor species. Large errors in the higher moments of the particle spectra (i.e., radar reflectivity) were shown to occur when conversion processes between hydrometeor classes strictly conserved particle number concentrations. The manuscript includes five appendices (one appendix is a complete list of symbols) that total thirty pages in length. The paper has already been sent for internal Goddard review, and I expect to submit it to the Journal of the Atmospheric Sciences within a week or two. Drs. Joanne Simpson and Wei-Kuo Tao were very kind and positive in their reviews of the manuscript.

Other activities this summer include working with Dr. John Scala on cloud model simulations of the 28 June 1989 North Dakota squall line case discussed at the Cloud Modeling Workshop in Toronto. The birth of my son at the end of July precluded my attending the Workshop. My collaborations continued with Dr. Bob

Pasken on analyzing the single-Doppler radar data from Darwin, Australia. Dr. Pasken will do case studies of a monsoon rainband and a break-period squall line, which I will follow with numerical simulations of these cases (hopefully) next spring. The single Doppler radar study of the evolution and structure of the 22 November 1988 island thunderstorm complex continues with Drs. Keenan and Simpson ; however, Dr. Simpson and I agree that this project requires more work before it can be published. It is likely that a series of sensitivity experiments using my one-dimensional time-dependent cloud model will be incorporated into the paper, as well as comparing these model simulations with convective clouds simulated in other geographical locations. Finally, Dr. Andy Heymsfield provided Dr. Tao and I with his recent analyses of CCOPE airborne microphysical data, as well as composite ice-particle spectra of Kwajalein cirrus at different temperature intervals: Both data sets appear to support several key assumptions I've made in the 4ICE scheme.

Much of my work in the upcoming quarter will concentrate on writing a second paper that compares GCE (Goddard Cumulus Ensemble) model simulations using the 4ICE microphysics of a tropical-maritime (tropical Atlantic) GATE squall line and a midlatitude-continental (southeast U.S.) COHMEX storm with radar observations of both systems. It will be shown that the model performed well in simulating the radar and microphysical structures of both convective systems, even though the observed vertical profiles of radar reflectivity differed substantially. A series of experiments will also assess the sensitivity of the simulated convection to variations in parameterized drop size distributions, fall velocities and aggregation efficiencies of ice, and ice nucleation at cold temperatures. Lastly, preserving the spectral widths of the particle distributions will also be shown to be more important than conserving particle number concentrations when converting between different hydrometeor categories.

I also expect to spend an increasing amount of time on preparing for my participation in TOGA COARE (Tropical Ocean Global Atmosphere Coupled Ocean-Atmosphere Response Experiment) this January, such as making hotel and travel arrangements, getting immunizations against a variety of tropical diseases, taking care of various insurance matters, preparing for five weeks of ship duty, and "brushing up" on several technical manuals that describe the operation of the shipboard radar. I also hope to get a "quick and dirty" version of the GCE model to run on a SUN workstation, so that I can do preliminary model simulations of a few cases while on the PRC ship #5 (soundings will also be taken from the ship). However, this is contingent upon how busy my schedule is at the end of the year.

970-021

21 October 1992

Subject : USRA Quarterly Technical Report

To : USRA

From : Jong-Jin Baik

Task Number : 970 - 021

1. Through extensive numerical model simulations and discussions with our project member, I now expect that numerical instability resulting from the liquid-ice phase microphysics can be removed by using a small time step for the terminal velocity terms for rain water, snow and graupel. This is very important because if it works, numerical simulations afterwards will go very smoothly. After obtaining model results, I will write a paper for journal publication.

2. I gave a seminar at Department of Astronomy and Atmospheric Sciences of Yonsei University, Korea, on 24 September 1992. The title was "Recent Research Trends on Tropical Cyclones".

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MEMORANDUM

TO: Denise Dunn, Administrative Assistant  
 From: Narinder Chauhan, Code 974  
 DATE: Oct. 22, 1992  
 SUBJECT: Quarterly Progress Report (July 1 to September 30, 1992)

The data collected during the summer of 1992 experiments conducted at Chickasha, Oklahoma and Boise, Idaho is being processed. The GSFC truck-based radar data has been labelled and arranged in a form that is easily identifiable and therefore easy to use. Though the radar operation was automated to some extent and the data was collected in separate files, but the software to determine the average radar return was not developed at the time of the experiment. This is being done now as an off-line operation and is 80-90 percent complete.

I participated in a microwave experiment on the Canadian forest with the Canadian Remote Sensing scientists from Sept. 21-26, 1992. Scientist had gathered at Petwawa Forest Research Institute, near Ottawa to study the signature of forest on microwaves. Canadian SAR (C and X-band) flew on September 25th and 26th. Multi polarization and multi frequency data was collected. We measured the dielectric constant of different components of the trees in the forest imaged by SAR. Ground truth data related to needle dimensions and their orientations was also collected.

Finally, my publication entitled "A microwave scattering model for layered vegetation" coauthored with Karam, Fung and Lang has been published in IEEE Transactions on Geoscience and Remote Sensing in the July 1992 issue. A copy of the publication is enclosed herewith.